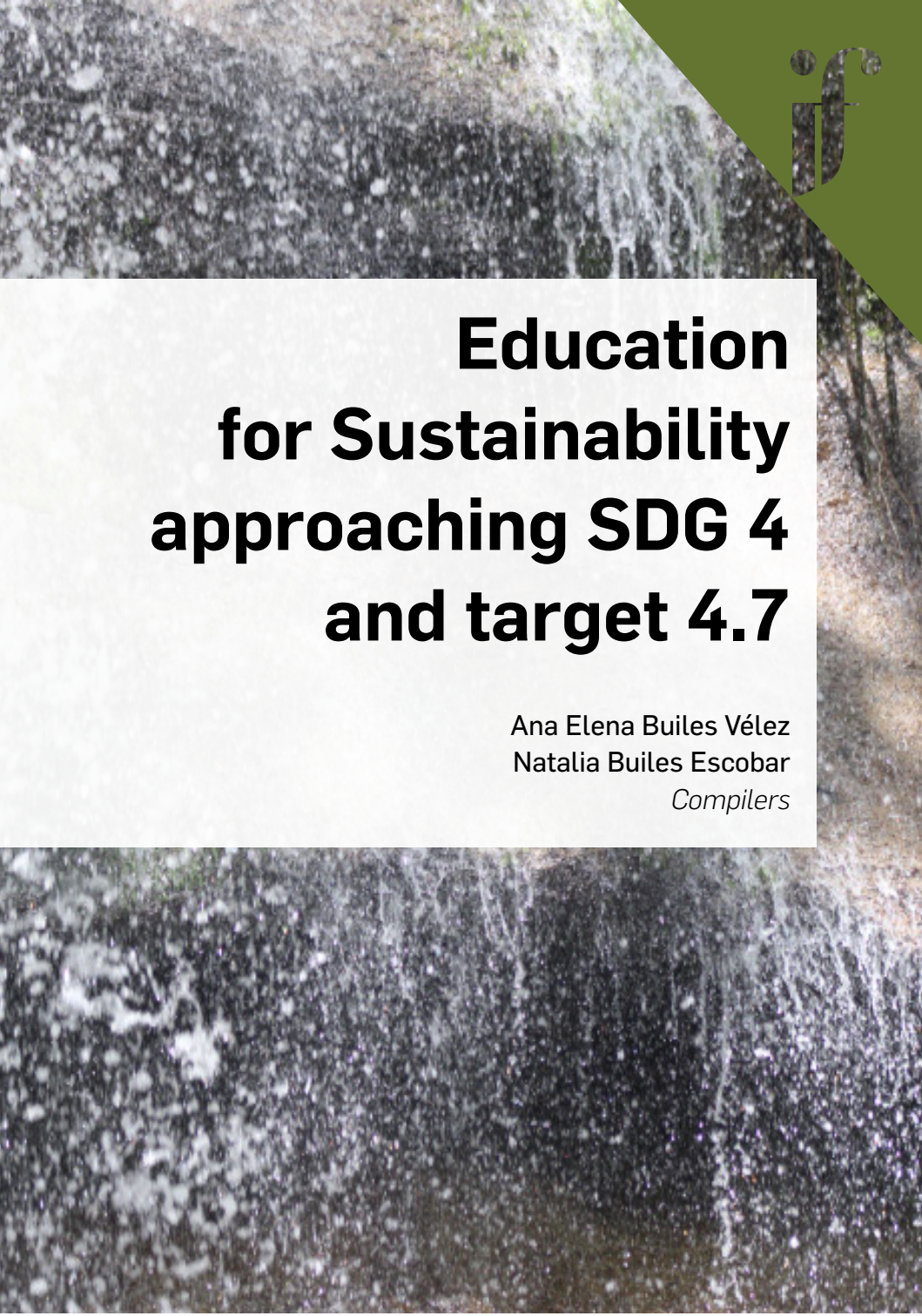

Education for Sustainability approaching SDG 4 and target 4.7

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Compilers

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

729

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Contents

Prologue

To face current sustainability challenges, we need to continue building, sharing, and applying the best possible knowledge to continue collaboratively developing solutions that allow us to improve how we live on our planet. In this, universities and other educational institutions have a crucial role in research, teaching, and service within the academic community and beyond[1]. In this role, educational institutions also contribute to building and strengthening technical and relational human capabilities[2]. It enables people to understand rationally better and emotionally connect more deeply with sustainability challenges and the diverse ways to continue solving them[3]. In strengthening capabilities to respond to sustainability challenges, the contribution of a diverse range of areas of knowledge is required in the learning dynamics. Some areas of expertise that have been known for their human-centered approach to innovation processes[4], such as architecture and design, play a significant

1 Wals, A. E. J., & Jickling, B. (2002). "Sustainability" in higher education: From doublethink and newspeak to critical thinking and meaningful learning. International Journal of Sustainability in Higher Education, 3(3), 221-232.

2 Chaplin, G., & Wyton, P. (2014). Student engagement with sustainability: Understanding the value–action gap. International Journal of Sustainability in Higher Education, 15(4), 404-417.

3 Tam, K.-P. (2013). Dispositional empathy with nature. Journal of Environmental Psychology, 35, 92-104.

4 Wu, K.-J., Liao, C.-J., Tseng, M.-L., & Chou, P.-J. (2015). Understanding innovation for sustainable business management capabilities and competencies under uncertainty. Sustainability, 7(10), 13726-13760

part in the search for ideas that propose new ways to meet the challenges of sustainability while promoting well-being for people and other life forms and the environment. From architecture and design, the range of possibilities to develop ideas is broad, ranging from the proposal of new products, buildings, spaces, services and processes to recent activities and lifestyles.

Those who work in education for sustainability in architecture and design need to continue strengthening the framework they teach, both from the academic and professional fields and from different spheres with stakeholders from the public, private and civil sectors. Here, a concrete way to promote better pedagogical processes is by incorporating objectives and activities into study plans that help students gain the skills they need to be more sensitive in front of sustainability challenges and capable of addressing them in *"the real world"* beyond their academic activities. They aligned this need to enrich the curricula with the global context from the perspective of the Sustainable Development Goals (SDGs), SDG4 in particular, which seeks to *"ensure inclusive and fair quality education and promote lifelong learning opportunities for all"*[5]. Of the different targets this SDG has, target 4.7 stands out for its direct relationship with the formation of knowledge and skills to face sustainability challenges within a creative and human-centered approach. This target aims in 2030 to *"ensure that all learners gain the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development"*[6]. The students should not only learn about how to "do the job" to meet academic and

[5] Retrieved September 28, 2022, from: https://sdgs.un.org/goals/goal4
[6] Retrieved September 28, 2022, from: https://sdgs.un.org/goals/goal4

professional requirements, but also do it while becoming more responsive to others' needs.

The pedagogical activities in the educational institutions where new architects and designers attend could benefit from concretely and clearly including SDG4 and target 4.7 in the curricula for distinct reasons. For example, projects would be more encouraged to go beyond their theoretical background and assess proposed solutions to sustainability challenges beyond the classroom to achieve a tangible impact on society and the environment. They could strengthen the pedagogical processes to help students equally enhance their technical and relational capabilities, learn to develop a new product while learning to be someone who knows how to better work in a team, for example. These learning dynamics with sustainability criteria could also facilitate a more integrated approach to solutions in architecture and design projects where the focus is maintained on analyzing the dynamics between people and their environment to evaluate the best way to address a sustainability challenge. It may mean that the solution to a challenge might not be addressed with the design of a new building or product, but a new way of building trust-based relationships in a specific community, for example.

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. They did 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.

I hope you enjoy reading the book and that it contributes to your daily activities to continue building better societies from sustainability through better learning processes, supported by innovation and focused on people and their relationship with the environment.

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Introducing a New Design Culture on Sustainability[1]

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Abstract

As promoted by Sustainable Development Goal 4, cultural and structural investments in high-quality education are important to ensure inclusive and fair quality teaching and promote lifelong learning opportunities for all. This is important considering Target 4.7, which promotes the education for Sustainable Development. The role of the Higher Education sector is paramount. To feed students' curiosity and empathy toward these issues, Design Universities should foster a new design culture hinged on

[1] This work presents the process used for the redesign of the Cultures module, a Year 2 module offered to all students enrolled in the BA (Hons) Product Design programme at the University of Lincoln, where the first themed contents on Design for Sustainability have been developed and integrated into Programme's Teaching and Learning strategies (T&L).

sustainability from the undergraduate level, as this topic is now relevant to any teaching agenda. Students trained in Design for Sustainability can benefit from a vast set of theoretical and design knowledge developed in the field since 90s. It is known that the cultural transition toward sustainability requires systemic changes and original learning processes linking contextual values and students' needs with strategic policies addressed by cultural institutions. To meet the above bottom-up and top-down drivers and to increase the quality of teaching, learning, and student experience, new modules are needed. This chapter presents the process used for the redesign of the Cultures module, a Year 2 module offered to all students enrolled in the BA (Hons) Product Design programme at the University of Lincoln, United Kingdom, one of the seven BA courses offered at the Lincoln School of Design. This work shows that introducing a robust design culture on Sustainability contributes to a higher quality of undergraduate design programmes with new teaching material and pedagogical methodologies, along with in giving students the chance to be an essential part of holistic and lasting learning processes conceived to converge learners' needs and design skills required by markets.

Keywords: Design Culture; Higher Education; Product Design for Sustainability; Service Design for Sustainability; Teaching and Learning Strategy.

1. Introduction

Many authors argue students are increasingly asking for sustainability to be included as a study subject in design programmes (Varadarajan, 2010), whereas Manzini and Jégou (2003) remarked on the need to act interdisciplinarity and synergistically. This not only because Sustainability is a key theme for present and future agendas, but mostly because there is an interplay between top-

down drivers from cultural and societal values, and bottom-up pushes fuelled by companies, market demands, and people's wish to consume new artefacts in a more conscious way. According to Vezzoli et al. (2018), Design for Sustainability is defined as a design practice, education, and research that contributes to Sustainable Development; after over thirty years of academic progress, it becomes a field characterised by a certain complexity (Ceschin and Gaziulusoy, 2020) with a variety of approaches that increase the chances of tackling the complexity of present times and foresee future living scenarios.

There is no doubt that sustainability is paramount for present and future society, and the Design discipline is entrusted with bridging the gap between cultures, markets, and people. Relevant pedagogic signals suggest that design students are now more aware of their potential to shape a better society through the sustainable artefacts that they can ideate, and this wish is stronger every day. It is not possible to discuss the value of teaching Design for Sustainability without considering the need to develop a strong design culture around it because any rhetoric triggers discussions about the methods and the essence of the Design discipline itself, which does not entail the mere translation of technical skills, but involves more delicate cultural actions aimed at training a new generation of thinkers with sustainable mindsets (Narasimhan and Kumar, 2010). Hence, before discussing 'how' a sustainable artefact can be made (re: product-centric approach), students must be invited to reflect on 'why' the society needs it (design culture). Understanding Sustainability requires a system-wide perspective to guide the interpretation of problems and conceptualization of solutions (Manna et al., 2022) and all design programs should shape local curricula having global foci (Manzini, 2010).

Since 2011, the University of Lincoln in the United Kingdom has recognised sustainability as one of the strategic values on which to base its growing strategy. This was reflected in a focus on research, curricula development, teaching, and the quality of campus. As a rapidly

growing institution with over 14,000 students, the University of Lincoln acknowledges that direct and indirect anthropic activities may have a dramatic impact on the living ecosystems (University of Lincoln, 2020a), and the entire community is called to a wider sustainable culture among the students' cohort to produce positive and lasting impacts on the teaching and learning strategies. This angle echoes the multidisciplinary visions of Sustainable Development promoted by the United Nations (United Nations, 2015; 2017) and recommended for academics (Keynejad et al., 2021).

A sustainable campus, a sustainable culture, and more effective collaborations for the change are the three pillars on which the University's sustainable strategy is articulated (University of Lincoln, 2020a). This led teaching staff to integrate a wide range of sustainability-related topics in many modules, both undergraduate and postgraduate, including the ones taught at the Lincoln School of Design, where sustainability is independently addressed via seminars and student-led initiatives.

The BA (Hons) Product Design programme is one of the seven undergraduate programmes currently offered by the Lincoln School of Design. It is a small and vibrant programme characterised by a student-centric philosophy and structure where learners can freely explore a wide range of topics through lectures, seminars, and studio-based activities. The programme aims to enable students to become skilled thinkers and creative designers with an understanding of target markets and consumer experiences. This philosophy was setting a new module wholly focused on Design for Sustainability–the 'Cultures' module. The programme positively meets the University's policy 'student as producer' set for undergraduate students (University of Lincoln, 2017), a research-informed teaching where students are at the centre of the learning process, and through which they can contribute to the University's cultural debate with first-hand experiences, simulations, and cultural discussions.

The Culture module is the first piece of a wider strategy of improvement aimed at increasing the programme's international competitiveness, reputation, and cultural quality of teaching modules with interdisciplinary contents designed to project students into modern avenues for the development of innovative skills needed to tackle the complexity of present times.

2. Aims

This chapter illustrates the strategy used to redesign the Cultures module, a 33-week core module offered to all Year 2 students enrolled in the BA (Hons) Product Design programme and the first design module completely focused on Sustainability offered at the Lincoln School of Design. The culture on Design for Sustainability within an undergraduate programme is here considered as a strategic value to improve the students' learning curves and tackle contemporary teaching challenges.

Specific module features such as structure, design philosophy, teaching and learning strategies, thematic foci, and student experience, are presented to show the value of the cultural approach used to create a new sustainable design culture that is positively improving the quality of the entire programme, and its horizontal organisation. Samples of student work on Product Design for Sustainability and Service Design for Sustainability–the two design foci proposed to students–are used to show the module's cultural impacts in relation to the new idea of Product Design promoted in the programme, which goes beyond the orthodox conception of 'designing objects'.

Finally, this chapter provides evidence underlining the benefits of teaching Design for Sustainability in undergraduate design programmes to trigger a lasting design culture able to improve horizontally and vertically the quality of teaching and students' skills development.

3. The design of the Cultures module

The design of a new undergraduate teaching module subtends to a delicate process that cannot be separated from considering the entire programme, as any improvement or change may cause systemic effects, both positive and negative. This assumption was used to establish the structure of the new module and place the teaching on Design for Sustainability in a holistic perspective. Giving students the chance to develop a first-hand design culture on sustainability was the main pedagogical value that has driven the redesign process.

This part describes the key features of the Cultures module in relation to the teaching and learning strategies for an undergraduate programme. Specifically, this part addresses the design strategy, the design culture on sustainability, the module's aims, the projects proposed to students, and the strategy used to assess the learning curves.

3.1. A strategy to create integrated teaching.

Before its reconfiguration, the Cultures module was not connected to other Year 2 modules. Whilst this intent has always assured a certain degree of flexibility to lecturers, it also produced a curricular fragmentation when related to the programme's philosophy. The first part of the redesign process was the creation of a resilient strategy to connect the module to the programme. Essentially, the module moved from a stand-alone configuration into an interconnected outline linking modules taught in Year 2 and functioning as a bridge between Year 1 and Year 3 (Figure 1).

As discussed, creating a design culture around sustainability means developing an integrated teaching strategy. Consistently with Figure 1, Figure 2 depicts the specific teaching elements included in the redesigned module, along with interdisciplinary peculiarities and themed design

Figure 1: The Cultures module in the BA (Hons) Product Design programme.

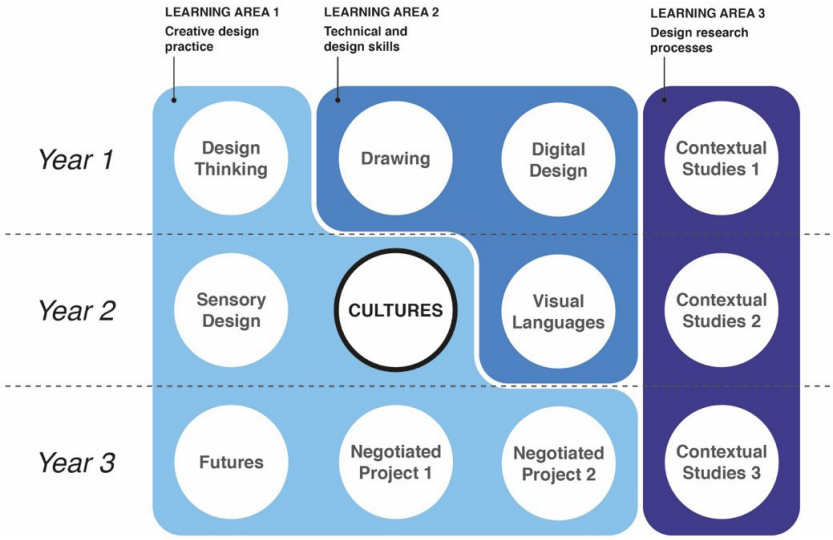
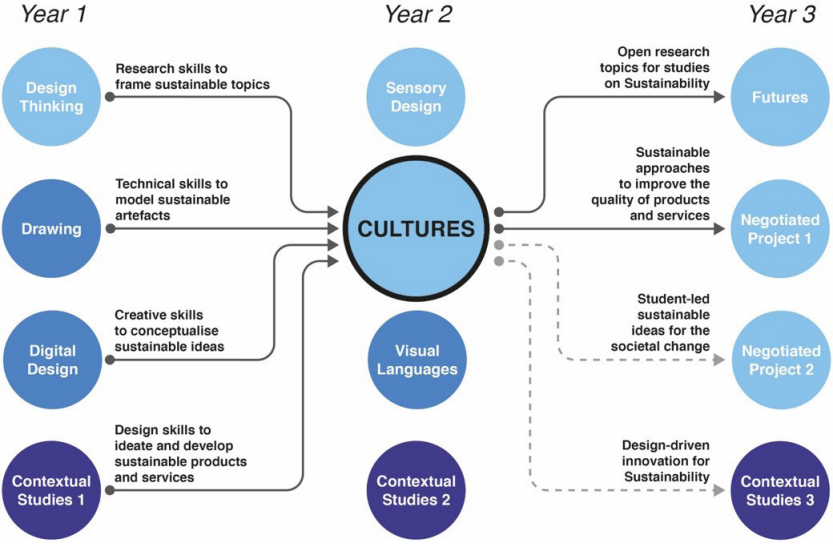


Figure 2: The Cultures module and the integrated teaching strategy connecting other modules.



elements coming from other modules. Figure 2 also shows how teaching elements coming from Years 1 and 2 have been adopted to produce a strong design legacy for Year 3 teaching.

This strategy to create integrated teaching provided higher quality and solidity to the programme's pedagogy and philosophy. From Figure 2, it is also interesting to see how this offered consistency to the overall student experience.

3.2. Developing a design culture on sustainability.

According to UNESCO (2021), the power of education lies in its capacities to connect us with the world and others, to move beyond the spaces already inhabited, and to expose to new possibilities; education nurtures understandings and builds capabilities that can help to ensure that our futures are more socially inclusive, economically just, and environmentally sustainable. This idea opens up reflections on the capability to employ a proper design culture to shape the world.

The new Cultures module has been conceived to intercept both top-down University policies and bottom-up student-led instances driven by societal changes. Current UK undergraduate students already show interest around Sustainability, though this feeling is often driven by the will to face 'traditional' issues related to the environment, such as mitigation of ecological threats, waste of resources, recycling, reuse of materials, etc. Only a few of them reflect in a systemic way by linking Sustainability to living ecosystems, aware business models, and social phenomena. Whereas it is known that Design for Sustainability also addresses economic and social factors, it is often interconnected with multidisciplinary patterns within the scenario of societal complexity.

Table 1: The values of the design culture on sustainability used in the redesign of the Cultures module.

Values of the design	Discussion
Value 1: Sustainability is a learning process.	As argued by Ezio Manzini (Willis and Manzini, 2005), the transition toward Sustainability requires systemic changes and social learning process. The module promotes own design approaches in the form of 'action to experience' by employing iterative processes.
Value 2: Think global and act local.	Consistently with Value 1, the extent of impacts produced by designable solutions suggests developing multi-scalar mindsets to place the designs in a twofold dimension: local, to assess the impact of projects in the mid-term, and global, to test the scalability and potential of interventions in the long run.
Value 3: Designing sustainable effects.	Instead of design sustainable products or services that may have an impact only in the short run, designing in the way of sustainability should foster reflections on how to design lasting sustainable conditions.
Value 4: Using contextual evidence.	Sustainability cannot employ naïve data or research process, otherwise Values 1 and 2 cannot be met. Therefore, contextual data extracted through first-hand methods are used to produce contextual knowledge frameworks on which to set up the projects.
Value 5: Innovation is upon meaning.	A sustainable project is not only a project that respects the environmental, social, and economic features, it is also a meaningful project. This value follows the Roberto Verganti's angle who says that contemporary customers buy products for their meanings, rather than functionalities (Verganti, 2009).

Values of the design	Discussion
Value 6: Differentiating impacts.	The differentiation of impact leads students to reinforce Values 2, 3, 4 and 5 by developing sets of coherent solutions, rather than by stand-alone projects working only in pre-selected contexts of use. This value also promotes creative thinking and problem solving.
Value 7: Studio collaboration.	Consistent with Values 1, 2 and 3, the studio environment must foster collaboration, respect, and open sharing. A studio environment based on fair collaboration is also a strong asset that positively influences both projects and the quality of the programme.

Source: Authors

The module's design culture on sustainability educates students to be confident in facing contemporary and future issues of the society, spanning from product design to service design applications. Therefore, the focus is on the value of design practice, ethics, creative intentions and meaning, rather than just technical design skills.

3.3. The Cultures module: Aims.

The module gives students the opportunity to develop a strong design culture on sustainability and focused cultural, methodological, and technical design skills–Design for Sustainability and sub-disciplinary approaches (Ceschin and Gaziulusoy, 2020). Through a structured use of design methodologies, students can gain confidence from a wide range of cultural angles commonly employed in sustainability studies. The module has been expressly designed to intercept student needs, feed their interest and encourage problem-solving skills, curiosity, and culture

by promoting an understanding of a wide range of creative responses determined by changes in societal trends, which specifically reflect and consider the cultural messages linked to the idea of Sustainability and its impact on reflective creative practices at significant scales. It requires students to recognize and respect cultural and methodological design aspects when transposing cultural indicators into sustainable products, services, and product-service systems.

Referring to the cultural design approach, the Cultures module requires students to challenge multidisciplinary issues surrounding social interaction, meaningful design, and inclusivity for sustainable solutions in real contexts of use. It also requires understanding the need to appreciate strains on natural resources in the sustainable production of goods, as well as focused methodologies to investigate user needs and wishes, new ways of consumption driven by contemporary trends, aware business models, advanced behaviours, and systemic interdependence between production and consumption practices. The module requires students to develop focused contextual analyses where research informs idea development on a project basis and generates empathy of ethical, ecological, and human approaches to sustainable design.

In terms of research and design approaches, primary and secondary research are an integral element of informing idea developments and generating sensitivity to ethical approaches to creative design practices. The module aspires to create an awareness of Social Inclusion and sustainability aspects for contemporary solutions, which leads to the development of innovative interventions on existing and new sustainable market niches.

Finally, the module benefits from the cultural collaborations and insights provided by the Estates Department at the University of Lincoln, which coordinates all University's activities related to Sustainability (University of Lincoln, 2020b).

3.4. The Cultures module: Topics, disciplinary foci, and projects proposed.

The Cultures module requires students to work on two projects for the University of Lincoln urban campus: a physical artefact (Product Design for Sustainability, project one) and a service (Service Design for Sustainability, project two). Projects interpret the strategic brief promoted by the University of Lincoln's Estates Department (University of Lincoln, 2020b) for student-led initiatives and aim to merge relevant cultural notions and methodological skills useful to work with Design for Sustainability on different scales. The choice to use the University campus as a testing ground reinforces the students' empathy toward a place they live and consume every day. This opens up deep reflections and effective transpositions in designing the best solution for themselves. This idea is consistent with the need to get closer to the research processes and design experimentations.

The Product Design for Sustainability project–'eco-solutions supporting human activities'–requires the specific gathering and analysis of cultural-ideological associations and sustainable relations for physical solutions usable by students, staff, and visitors. The 'sustainable qualities' of designable solutions concern the creation of harmonies amongst eco-performances, production and assembly criteria, semantics, aesthetics, and analysis of human-product interactions. Students are asked to design a coherent sustainable solution that meets themed cultural attributes on a 'humanistic' and 'object' basis for experiences within targeted cultural spaces. The traditional idea of 'commercial object' is developed into the design of 'sustainable artefact' promoting contextual values, anthropic activities, and ecological aspects. The Service Design for Sustainability project–'smart services connecting people, places, and resources'–investigates value-based associations and ecological relations for intangible solutions–services and product-service systems–

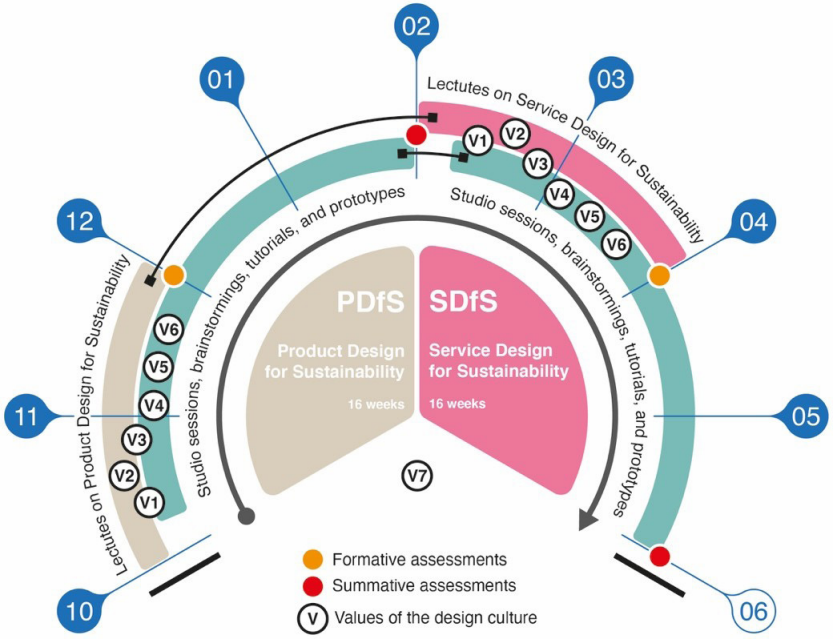
usable by all universities to improve the sustainable quality of their campuses. The 'sustainable qualities' of considered services concern the creation of innovative relations between people, activities, operational environments, and resources.

In terms of disciplinary foci, students are guided into relevant disciplinary notions through focused lectures and seminars to develop cultural design frameworks linking human activities, living ecosystems, and designable solutions. They are guided to develop their design consciousness on Design for Sustainability and an understanding of how to work using merged methodologies and learning-by-doing research approaches. The projects also aim to develop students' ability to design meaningful proposals by investigating relevant concepts and contemporary cultural issues to assess the impacts of anthropic activities in modern ecosystems.

3.5. The Cultures module: Structure.

Students spend a 16-week period for each project and are guided into relevant notions and design concepts useful to properly understand peculiarities and strengths on Product Design for Sustainability and the Service Design for Sustainability domains. Figure 3 illustrates the structure and features of the Cultures module in relation to the projects.

Figure 3: The Cultures module: Structure.



3.6. The Cultures module: Skills development and learning outcomes.

The assessment of student works is a crucial aspect to consider when designing the module, as this should provide consistent feedback on which students can assess their performance in relation to the learning outcomes, including showing how to improve all aspects of their projects. To meet the University's standards and to provide high-quality feedbacks to learners, the module employs both formative assessments (Weeks 8 and 25) and summative assessments (Weeks 17 and 33).

To learn outcomes, at the completion of the module, students will be able to:

- Recognise emerging sustainable market niches for new product and service development.
- Identify research findings into consumer groups to address projects' briefs and sustainable design experimentations.
- Analyse ethical values and their implications for sustainable artefact development, and act responsibly within social and professional contexts.
- Determine innovative research-driven strategies for concept generation that match contextual analyses, scenario development, human-centred analysis, materials, etc.
- Select design findings into existing sustainable artefacts to decode potentialities to be applied in new projects.
- Work and be confident with both tangible and intangible sustainable solutions–and on how values - to develop autonomous thinking needed to converge these disciplinary areas.
- Foster cultural alliances and recognise the cultural relevance of transposing sustainable tribalism into product and service design.
- Take mature decisions to determine meaningful design directions in Product Design and Service Design domains, at all scales.
- Communicate sustainable values to wider communities through design experiences.

4. Results and student projects

Both Product Design for Sustainability and Service Design for Sustainability projects give students the chance to experience Sustainability by proposing personal reflections, empathy, and curiosity. The structure of the module and the chance to work on a familiar testing ground allow students to go beyond canonical ideas and research issues. In the first two years since its introduction, students have shown firm commitment to bringing first-hand experiences and values which reflect originality and a willingness to explore unconventional topics. For instance, outstanding

projects developed in the Product Design for Sustainability domain concerned tangible artefacts to improve the recycling processes on campus, modular relational areas to relax and study (Figure 4), 'green' objects to self-produce foods, promote biodiversity, or improve the students' mental health (Figure 5), and stackable products to protect the natural areas and the local wildlife, and artefacts to empower the production of energy.

Projects made in the Service Design for Sustainability domain opened up students' critical thinking in considering the impact of anthropic actions on the local territory. Field analyses allowed students to identify sensitive topics for their everyday life, such as relational architectures to swap tangible and intangible goods, smart applications to improve the recycling processes and develop informal economies (Figure 6), services to stay healthy and reduce food wastes (Figure 7), and services to employ student skills to self-produce primary goods.

Overall, the design culture on Design for Sustainability reflected in a stronger awareness of students' skills as well as higher impacts on Year 3.

5. Conclusion

The creation of a new design module centred on Design for Sustainability at undergraduate level, which is the first time where learners get in touch with structured academic notions on Sustainability and transition studies, causes profound examinations of the programmes' philosophy where this module is expected to contribute, as this new complexity opens to reflections that goes beyond the mere sharing of notions. This aspect is very important because is consistent with the Target 4.7–'education for Sustainable Development and global citizenship'–part of Sustainable Development Goal 4–'Ensure inclusive and fair quality education and

Figure 4: An eco-solution to study and relax (Student: Louis Wise).

Figure 5: Green pod supporting local biodiversity (Student: Charlotte Soukal).

Figure 6: A collaborative service to encourage students and staff to recycle items that can't be recycled through normal council collection (Student: Katrina Wood).

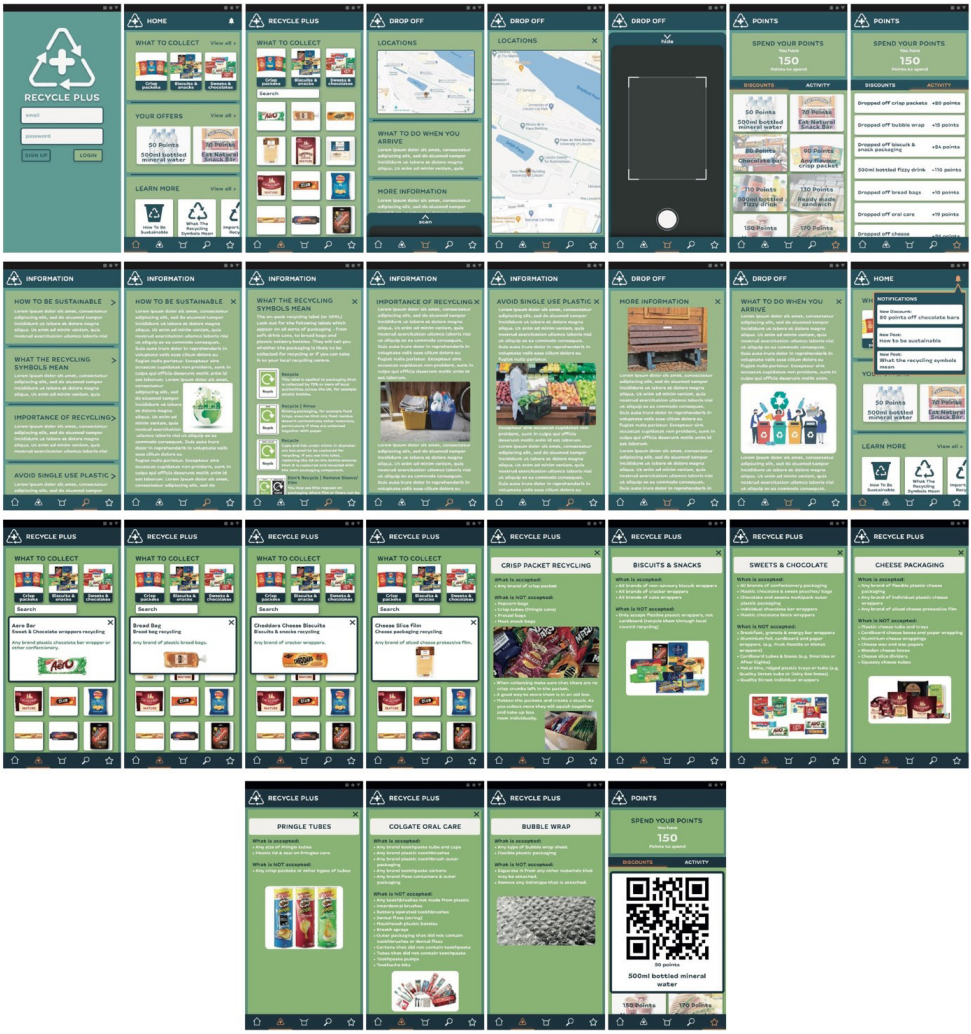
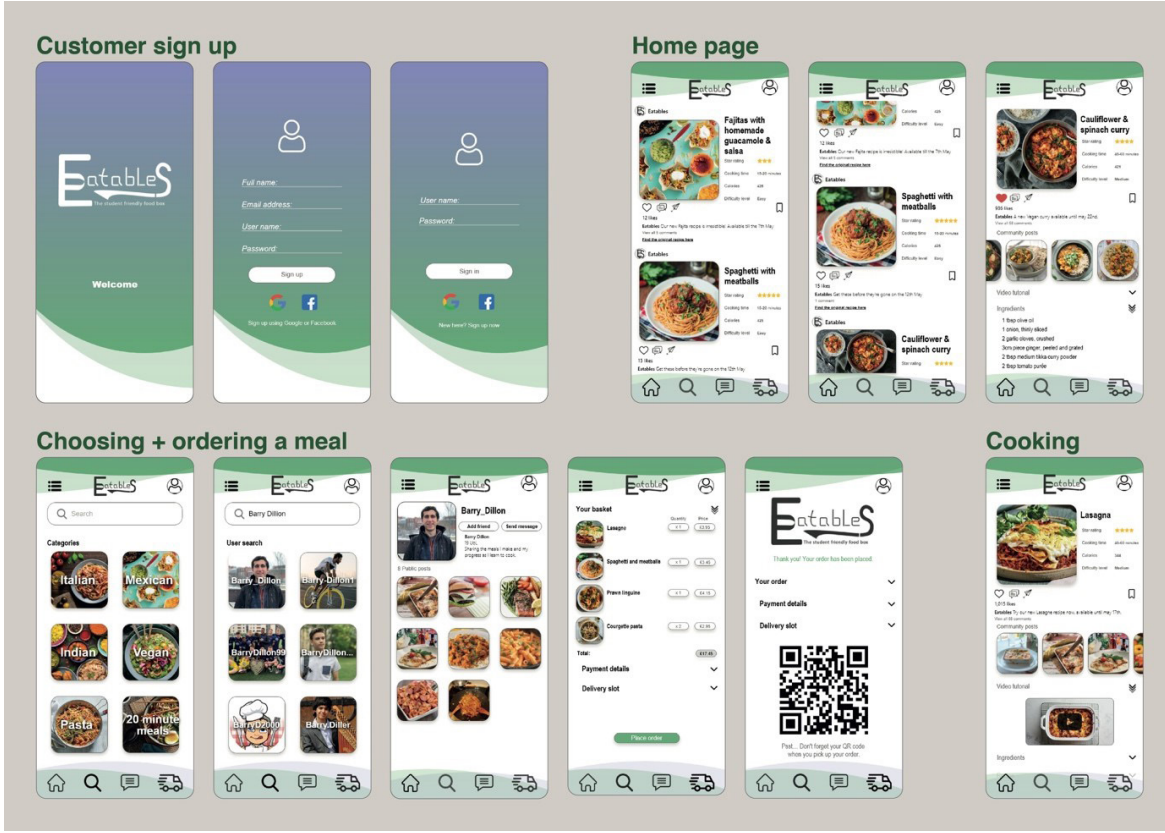


Figure 7: A service to mitigate the waste of food within the student community (Student: Declan Greene).



promote lifelong learning opportunities for all'–which opens up important debates to teach challenges, learning opportunities, and students' experience (United Nations, 2017).

As discussed in this chapter, the chance to qualitatively contribute to the Lincoln School of Design's offer elicited innovative interpretations on the idea of Product Design, which at the University of Lincoln is now intended as a modern discipline having a strong tradition and a capability to face the contemporary issues of the sustainable society; it is connected with new research areas by employing advanced teaching methodologies that include students into a holistic learning process pairing human values led by students and design skills required by markets. The recorded students' feedback also shows the positive impacts of this cultural change, as they feel more in touch with modern academic disciplinary debates, and through which they are more able to shape a solid reflective, creative practice.

The experience discussed in this chapter also shows that, if well calibrated to meet student needs, it is also possible to situate the new sustainable design culture within merged teaching scenarios, whereas the changes occurred aim to increase the quality of the teaching experience. At a School level, introducing the new design culture on Sustainability has positively improved the quality and reputation of the BA (Hons) Product Design programme and triggered cascade improvement processes that are involving even Year 3 modules, where topics related to the social dimension of Sustainability, such as Social Inclusion and Social Innovation, have been introduced.

6. Discussion on teaching and learning

In addressing issues of Sustainability, the projects set out in the Cultures module present students with a set of complex or 'wicked' problems that may contain multiple stakeholders and relate to a variety of systems, influencers, and potential impacts (Rittel and Webber, 1973). These briefs require students to reflect on the problem from several angles and hold multiple considerations in mind as they work to come up with a viable solution.

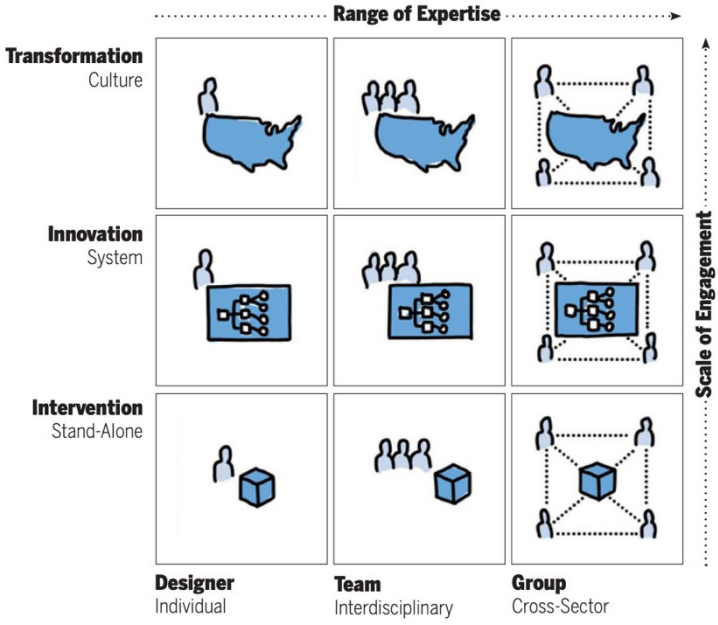
Development of skills is a tremendous opportunity. the projects provoke deep analysis and sometimes a need to question personal assumptions or 'lazy thinking'. The complexity of the briefs enables the learning outcomes involving analysis, reflection, determining, mature decision-making to come into focus. In their Design studies prior to this Year 2 module, (in school or college and earlier in the degree course) students have had experience with briefs that require a physical solution, sometimes for one client, with a clear set of needs/requirements. The benefit of stretching students and presenting them with briefs that are not so easily addressed is that they become more reflective, sensitive, and aware.

The 'live' nature of the briefs and the collaboration with the University Estates Department offer the students the opportunity to find solutions to tangible problems. This real-world connection enables 'authentic learning' to take place (Herrington et al., 2014). Assisting students to develop complex skills such as systems-thinking is strengthened by this approach, as Rieger (2021) suggests in relation to the teaching of inclusive design.

Irwin et al. (2020) discuss how complicated problems can be answered by solutions of varying complexity and expertise in the Winterhouse Social Design Pathways Matrix (Figure 8). This matrix shows the range

of responses that students can present within the Cultures module. All viable, but with differing levels of sophistication.

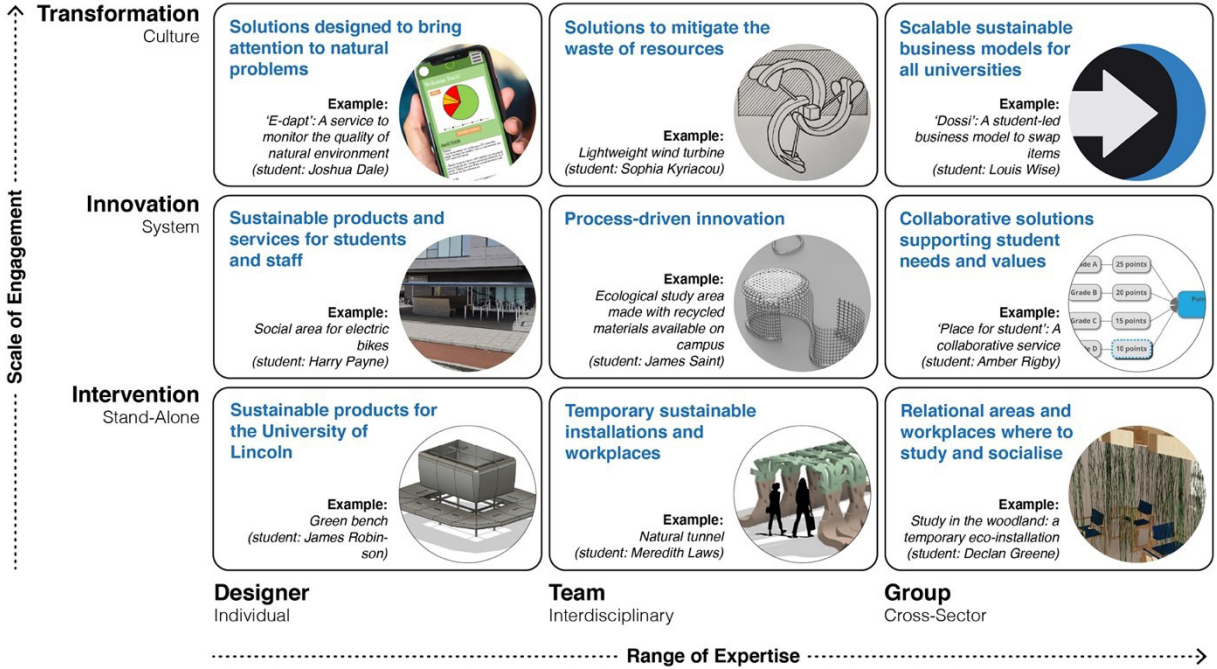
Figure 8: Winterhouse Social Design Pathways Matrix (Irwin et al., 2020).



This model was populated with examples of projects produced in the Cultures module to show the increasing level of impact and leverage as you move towards the top right corner of the grid (Figure 9).

Projects within the grid can be loosely projected onto the BA (Hons) Product Design mark scheme where a grade of 40-49% is apportioned to work that conveys “limited understanding” and “little or no attempt to relate issues to a broader framework”. A first-class grade of 70% or higher is awarded to work that shows “analytical thinking, high-level problem solving and an ability to synthesise material effectively”. It is

Figure 9: Solutions from the Cultures module.



valuable to have such a range of potential responses–and levels. The briefs do not exclude students that are operating at a lower grade point but provide ample space for higher-level work.

Exposing students to systemic, social, and cultural designs for change expands their perspective on the potential of design and increases the ambition of many. This module provides the opportunity for extremely high-level analysis, consideration of multiple variables and relationships and sensitive methods of driving transformation. On completion of this module, many high-achieving students develop their skills in systems-thinking and social awareness. Year 3 modules offer students more control over their project briefs, with the opportunity to create their own. On moving on from the new Cultures module, many students are choosing to work on service, system, and social design.

A potential development for this module teaching is to develop a multidisciplinary group aspect to the project work, a strategy identified by McCune et al. as favoured by many who teach wicked problems in higher education (2021).

Author contributions

All authors have equally contributed to the study's conceptualisation and development. The writing of the different sections is attributed to Emilio Rossi for 'Introduction', 'Aims', and 'The design of the Cultures module'; to Alexa Mottram for 'Abstract', 'Results and student projects', and 'Conclusion'; to John Stocker for 'Discussion on teaching and learning'.

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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.

Keywords: DIY-Materials, bio-based, bio fabricated, material education, material design.

DIY-Materials Approach

In the history of humankind, materials have dictated the shape of human reality, influenced the human skills of making and its evolution. The growing awareness of the impact the misuse and overuse of materials plays in determining emerging environmental issues is remodulating our material reality. The design community is therefore committed to foster a better understanding of materials' impact (Pollini and Rognoli, 2021), reasoning about the use of materials on a design level. Craftspeople or

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

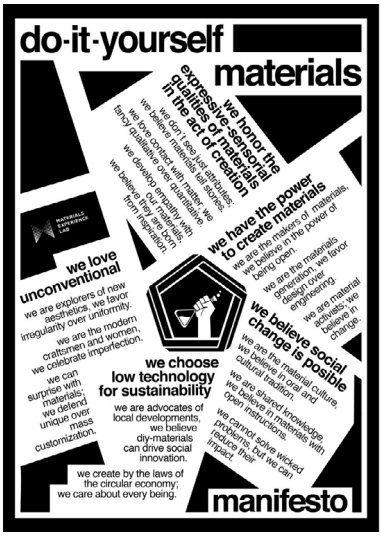

Photo credits: Camilo Ayala-García, 2017

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.

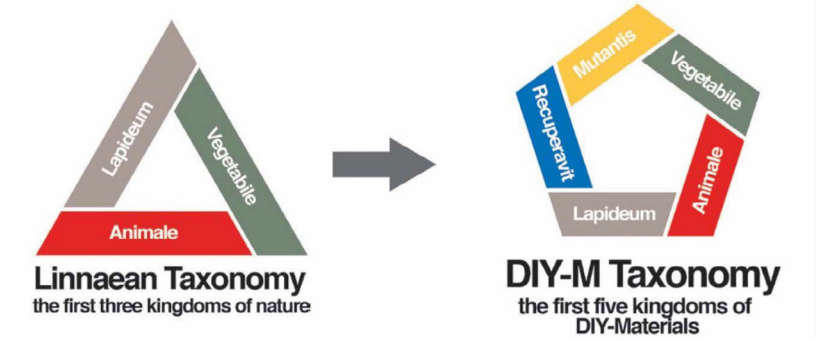

Photo credits: Camilo Ayala-García, 2017.

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

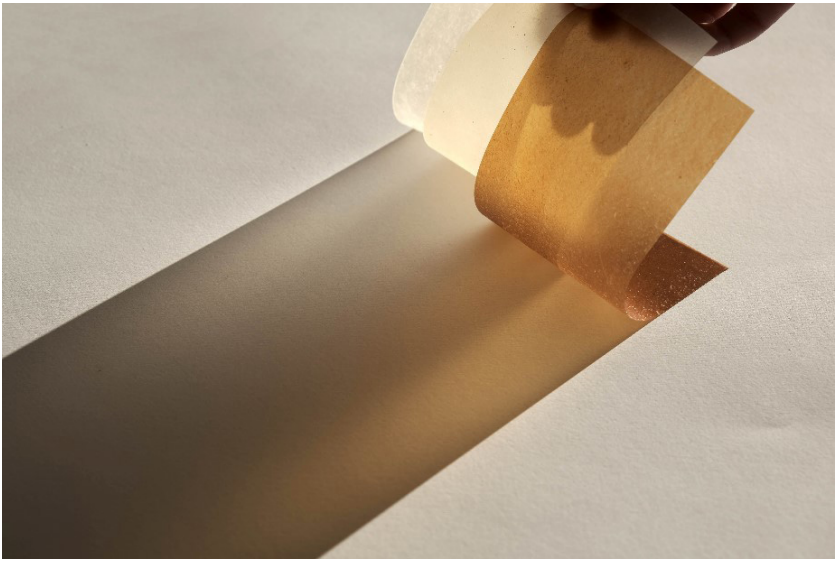

Photo credits: M. Grisa, 2021

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

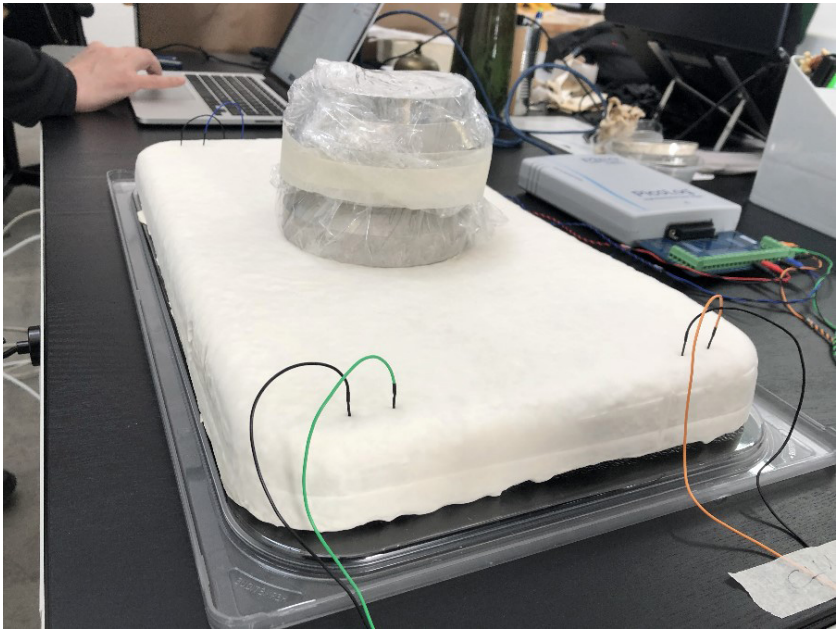

Photo credits: A. Albergati, 2021

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

[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.

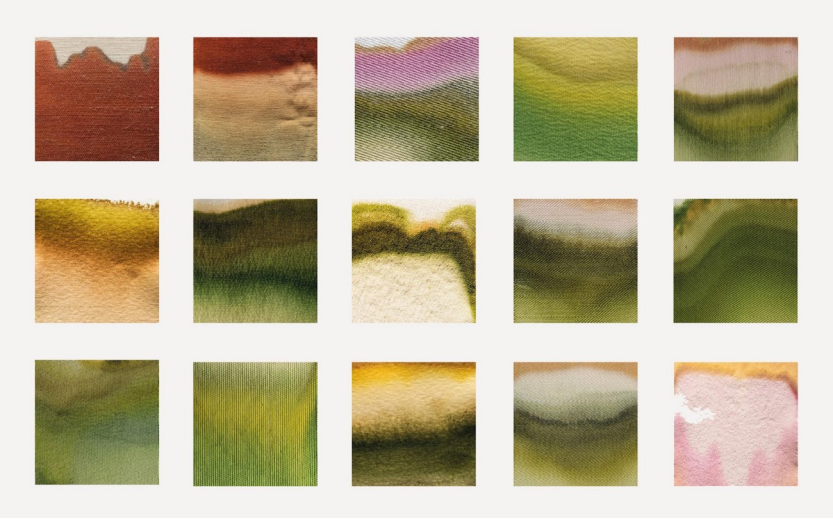

Photo Credits: B. Cerlesi, 2019

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

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Abstract

The aim of 193 countries working toward 17 goals requires knowledge and involvement from every single person, and the SDG Fortune Teller is a good start. As Chair of Education of the United Nations Association in Orange County, California, U.S.A., the feeling of responsibility and urgency spreading this relevant message was clear. As a result, a tool was developed. An easy to use, affordable, colorful, and fun tool to help educators, and the public learn about and spread the 2030 agenda: The SDG Fortune Teller. By using the ancient art of origami, we can use paper to construct two SDG Fortune Tellers, where each fortune teller contains 8 of the 17 goals. Goal 17 is placed on the back to reinforce the concept of partnership. The Fortune Teller can be incorporated into any curriculum by any teacher and instructor, but also has the potential to be used in any presentation around the 2030 agenda since it taps curiosity, releasing dopamine, and activating long-term memory. The ultimate purpose of

this tool is to support the agenda, by people becoming familiar with the SDGs and eventually turning passions into actions by thinking globally and acting locally.

Keywords: SDGs, tool, Education for Sustainable Development, curiosity, agenda 2030.

The Sustainable Development Goals (SDG) Fortune Teller

The United Nations (UN) has been actively leading efforts toward international development since their inception in 1945. However, their approach has been shattered and disjointed until the 90s when finally, three main pillars were adopted to work collectively to promote economic, social, and environmental development. (Kumar, Kumar, & Vivekadhish, 2016). These three main pillars were key in the Millennium's adoption Development Goals (MDGs) in 2001 by putting people and their needs upfront.

According to Ban Kin Moon, the MDGs presented a variety of reasons for shortfalls in progress towards the 8 goals for 15 years. The main reasons are "lack of progress to unmet commitments, inadequate resources, lack of focus, and insufficient interest in sustainable development" (Fehling et al., 2013). For others, the MDGs cannot be fully met because of how the goals were designed (Clemens, Kenny, & Moss, 2007), lack of metrics, civil society was not involved, and the agenda was only designed for developing countries.

According to the United Nations, 193 countries adopted a new set of goals in 2015. The new agenda's primary focus was based on finding a

balance between planet and people considering prosperity in order to achieve the peace we all want.

According to the United Nations (2015) report, with this in mind, 193 countries gathered in the United Nations' Headquarters on September 2015 and agreed on a new set of global goals that will replace the Millennium Development Goals MDGs. A new agenda was born with a new set of goals: The Sustainable Development Goals (SDG). This new agenda will be effective for the next 15 years and it will be our road map, a new blueprint to achieve a better and more sustainable future for all of us and our upcoming generations (United Nations, 2015).

But how do the MDGs differ from the SDGs? The MDGs did not have an active role in the civil society organizations (Waage et al., 2010). Another flaw was that this agenda was conceived by government heads and leaders. In addition, the MDGs had little emphasis on social justice, equity, empowerment nor human rights (Fukuda-Parr, 2010). Meanwhile, the SDGs to begin with, its conception and design reflect the collective work from the beginning. Unlike the Millennium goals, the new agenda was not designed top down, but the community was fully involved from the beginning in a bottom-up manner. Popular consultations were held globally, and over 7 million people shared their priorities, challenges and what they face every day. The findings were collected using a platform - MY World 2015 (https://vote.myworld2015.org/). Similarly, to the MDGs, the new findings cover issues such as health, poverty, and education, but other elements were added, such as climate, life below water, peace, justice, and partnerships were incorporated to achieve the objectives. This agenda is inclusive, and its logo represents a circular system, which reminds us that all the goals are interconnected and there is no hierarchy but a symbiotic relationship between the goals.

The result is an agenda that reflects the intention and commitment of 193 member countries of the UN. The promise of working collectively

to forge a better future, by eradicating poverty and injustice, and instead working toward dignity for all while nurturing respect for our planet.

Another difference between the MDGs and the SDGS is that the new agenda has instruments to assess whether the goals are being achieved. There are metrics, 17 goals were adopted with 169 goals that serve as a guide for evaluating progress and compliance for 15 years. Unlike the MDGs, the civil society can contribute their suggestions on priorities and progress using Myworld 2030 - http://myworld2030.org/.

In addition, it is critical to understand the 2030 agenda is not just another framework for governments and nonprofits to drive growth and purpose (Da Costa, 2019) but the SDGs are a critical step toward human development (Kwee, 2021) by enriching society in different fronts such as social, cultural, political, even technological, and economical around a human axis around nondiscrimination, equity, and human rights.

With this in mind, the private sector is a key stakeholder that could boost and speed up implementing the SDGs by 2030 (Rashed & Shah, 2021). More and more companies across the globe have incorporated the 2030 agenda as a cross-sector collaboration addressing global challenges, by meaningful partnerships and programs around the 17 SDGs (Coca Cola Company, 2022). Coca Cola, for instance, is a strategic partner to achieve the agenda, not just because of its commitment and contribution disclosing the advancement publicly, but also it is an entity that can help with the metrics. The United Nations only has presence in 193 countries meanwhile Coca Cola has presence and operates in 200 countries (Coca Cola, 2022).

Companies worldwide have discovered the power of sustainability by tapping into the SDGs through corporate social responsibility, environmental initiatives, and a circular economy. All these areas are required to support the implementation of SDGs. The SDGs tied well with

brands, since consumers today don't just buy a product or service; but they are looking for a deeper purpose. They want to build relationships with almost the entire supply chain; from manufacturers with values to producers. Users are constantly evaluating the dynamics of consumption and how it affects the environment (Lazebnikov, 2021), how responsible and ethical companies are with their vendors, clients and even workers.

According to the World Business Council, Colombia has done a decent job with the SDGs by incorporating them into the 2014-2018 National Development Plan. It was one of the 20 countries that publicly and voluntarily shared their progress in 2016. In collaboration with the Swedish government, a virtual platform was developed to publish and communicate the objectives, developments, progress, and metrics of each goal by promoting transparency (Reyes, 2022). According to the World Business Council for Sustainable Development in 2018, public and private companies in the sector were pioneers by incorporating the SDGs into their internal plan. This reflects the important role of the private sector in Colombia with the SDGs and the proper compliance with the 2030 agenda. This effort was led by 19 companies summarizing and breaking down their contribution toward sustainability by emphasizing their goals, management, and strategies (Reyes, 2022).

The companies that were part in this sustainability initiative were: Pavco, Postobón, Seguros Bolívar, Telefónica / Movistar and Tigo UNE, Amarilo, Bavaria, Cámara de Comercio de Bogotá, Cemex, Condensa y Emgesa (Grupo Enel), Constructora Bolívar, Corona, Davivienda, Ecopetrol, ElectroHuila, Findeter, Holcim, Itaú. (Reyes, 2022). (It is important to highlight the list does not have a particular order of contribution or priority).

As the years pass, the year 2030 looks closer, and the agenda gets a sense of urgency. According to the United Nations report in 2022, the proper progress toward the SDGs has slowed down, and the pandemic has disrupted our track (The United Nations, 2020).

That is why to reach the 2030 agenda. We need not just the work of governments, and the private sector, but also NGOs and civilians working collectively. Individuals must become change-makers. They require the knowledge, skills, values, and attitudes that empower them to contribute to the sustainable development goals, and education is key providing the proper competences to do so. According to Kwee (2021), students should be better equipped with self-directed learning, critical thinking, problem-solving and future-oriented skills that drive solutions to achieve environmental integrity, economic viability, and social justice. Educators have not been trailblazers promoting the SDGs. It is clear the educative system is falling behind spreading and advancing the 2030 agenda because of the lack of support, tools and training encompassing the SDGs. According to Kwee (2021), "instructors' personal beliefs are aligned with the proper incorporation of the SDGs if there is a school plan or curriculum reorientation supported by professional training with proper tools". As seen in Smith et al. (2016, p.37) publication, this is even more critical when teaching and mentoring designers since design can be understood as a powerful practice that takes part in giving form to the future" (Smith et al., 2016, p.37). There is no area more fundamental to sustainability future than design, specifically the balance between design and environment: "the story of design is the story of our relationship with the environment" (Skene and Murray, 2015, p.280).

So, if we think about our future as agents full of purpose capable of achieving environmental integrity, economic viability, and social justice, it can be very convoluted and almost utopian (Keith et al., 2019).

That is why it is imperative to provide better opportunities for Education for Sustainable Development (ESD) and social design capable of bridging the gap between theory and practice (Gaughwin & Ellice-Flint, 2021). We know instructors are pivotal agents bridging this gap by empowering students in the classrooms and properly engraving the SDGs. This knowledge will be carried on once the students are active

leaders and contributors to society (Rieckmann, 2017). In order to include the SDGs into the curriculums in ESD and social design, we cannot expect to incorporate a traditional approach but an interdisciplinary and holistic method (Biasutti et al., 2018) by considering the subject and students' learning outcomes (SLO) as well.

Desing process

The SDG Fortune Teller is a tool designed by Isabel Treidl, chair of education and young professionals in the Southern California, United Nations Association, to help spread the 2030 agenda. The goal was to support educators and instructors by providing a fun and engaging framework to introduce the agenda and generate projects around the 17 goals.

The idea was tested locally, and later at the division level. That is why this tool has been translated not only into the official languages of the United Nations (English, Spanish, Russian, Arabic, French, Mandarin, and Portuguese), but also Japanese, German, Hindu, and Farsi. Currently, working in Vietnamese, Ukrainian and Hawaiian; It is key to constantly adding more languages because it is believed that such a complex agenda needs collaboration in every corner of the planet (Treidl, n. d). By tapping into more languages, more collaboration can be brought into the table. According to the American Psychological Association, "collaborating across cultures and growing beyond the boundaries of self-interest offers a way forward for progress on the world's big issues" (Clinton, 2019).

Method

A tangible tool was created: The SDG Fortune Teller. Its purpose is to inspire and serve as an aid not just for educators but individuals to ensure

we become familiar with the 17 goals and "all learners gain knowledge and skills needed to promote sustainable development, including among others through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship, and appreciation of cultural diversity and of culture's contribution to sustainable development" Teachers, instructors, docents and even presenters can access this tangible tool to teach the Sustainable Development Goals inside their classroom, workshops or any conference or event where this topic is relevant. (Treidl, n. d)

The idea is simple: two SDG Fortune Tellers. SDG Fortune Teller 1 has the first eight SDGs (Figure 1) and the other one has the remaining 8 SDGs (Figure 2). Both work together, you can play with one or both. The last SDG, #17, is on the reverse side of the paper as a large picture. This is because the fortune teller works with multiples of 8, but also because Goal 17 is Partnership for the Goals. This goal is vital, since it shows the importance of cohesive and coherent work among all governments, entities, and individuals. Finally, the reverse side of the SDG Fortune Teller (Figure 3), besides having SDG #17, has the UN SDG website as a reference resource. Teachers, educators, kids, and parents can access the website to learn more about the goals. (Figure 4) (Treidl, n. d). Find the tool Appendix A. Online https://www.una-oc.org/fortune

The SDG Fortune Teller idea is more than a colorful piece of paper that has the potential to create a fun, engaging experience that promotes the learning of the 17 SDG. It is a tool for joyfulness that increases curiosity, which is the primary fuel for deep learning. (Perry, 2000) By tapping curiosity, students learn more and learn better (Ostroff, 2016). Curiosity can release dopamine, which makes the hippocampus function better, or activates long-term memory (Ostroff, 2016 P. 5). The Fortune Teller has colors, numbers and images in a configuration that helps the

Figure 1. Fortune Teller 1 SDG (1-8)

Figure 2. Fortune Teller 2 SDG (9-16)

Figure 3. Fortune Teller Reverse SDG# 17

Figure 4. SDG Website

user to become more familiar with the SDG and eventually learn them by heart in a natural process.

The SDG Fortune Teller is also a metaphor for our future. Can we tell how it is going to be? Can we guess? Maybe not, but at least we all can work toward our future, a better future. That is why 193 countries agreed to work on 17 goals for 15 years. By 2030, we expect our future will be better. Over 2,000 SDG Fortune Tellers have been distributed. The SDG Fortune Teller has been in notable hands, such as the past president of the United Nations general assembly H.E. Peter Thomson from Fiji. Even Ban Ki-Moon and António Guterres have enjoyed the tool by tapping their curiosity and playfulness. The Fortune Teller has visited colleges, universities, and even Capitol Hill in Washington DC and the General Assembly in New York, promoting the SDGs and raising awareness of the 2030 agenda.

Table 1 summarizes some competences that can be developed by using the SDG Fortune Teller with projects around the 2030 agenda (Van Norren & Beehner, 2021).

Table 1. Competences for Sustainability defined by UNESCO

Competences	Description
1. System thinking competency:	The ability to recognize and understand relationships to analyze complex systems; to think of how systems are embedded within different domains and different scales; and to deal with uncertainty.
2. Strategic competency:	The ability to collectively develop and implement innovative actions that further sustainability at the local level and beyond.

Competences	Description
3. Self-awareness competency:	The ability to reflect on one's own role in the local community and global society to continually evaluate and further motivate one's actions; and to deal with one's feelings and desires.
4. Collaboration competency:	The abilities to learn from others to understand and respect the needs, perspectives, and actions of others (empathy); to understand, relate to and be sensitive to others (empathic leadership); to deal with conflicts in a group; and to facilitate collaborative and participatory problem solving.
5. Critical thinking	The ability to question norms, practices and opinions; to reflect on own one's values, perceptions and actions; and to take a position in the sustainability discourse
6. Problem-solving integration	The overarching ability to apply different problem-solving frameworks to complex sustainability problems and develop viable, inclusive and fair solution options that promote sustainable development
7. Normative competency:	Understand and reflect on the norms and values that underlie one's actions; – negotiate sustainability values, principles, goals, and targets, in conflicts of interests and trade-offs, uncertain knowledge and contradictions. (UNESCO, 2017)
8. Anticipatory competency	The abilities to understand and evaluate multiple futures–probable, and desirable; to create one's own visions for the future; to apply the precautionary principle; to assess the consequences of actions; and to deal with risks and changes.

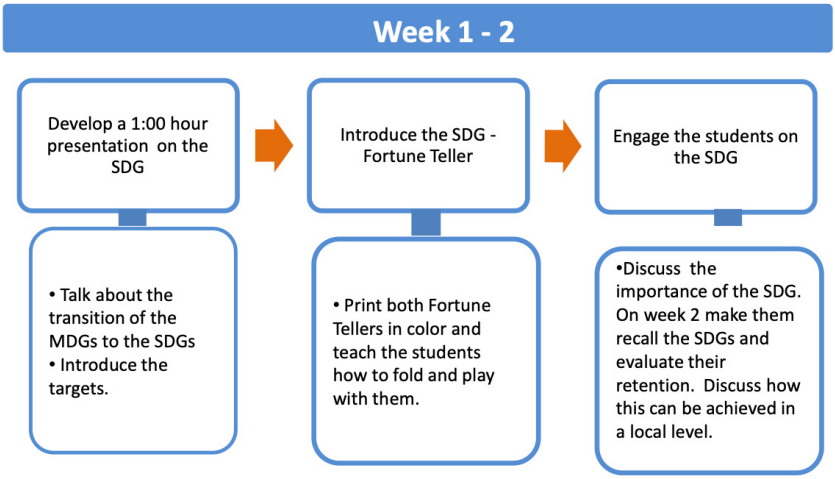
Source: UNESCO (2017).

Ways of Using the SDG Fortune Teller:

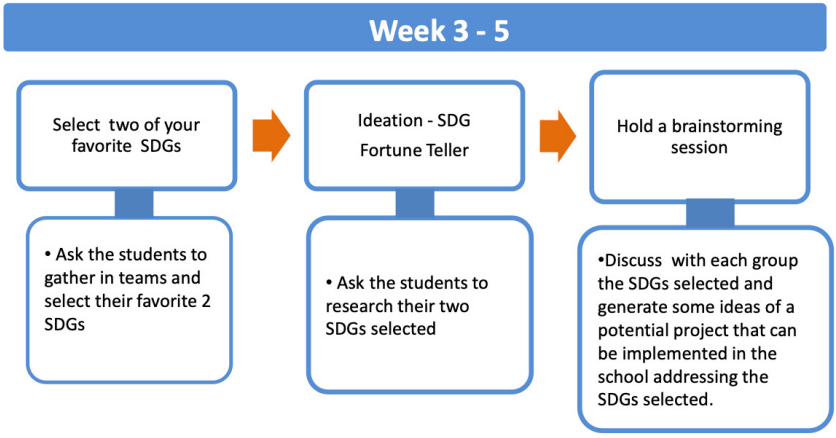
- Introduce the transition from the MDGs to the SDGs.
- The SDG's Fortune Teller tool can be downloaded at no cost https://www.idea-dispenser.com/public-speaking-and-storytelling. Once the students are familiar with the agenda, they can select a specific goal (s) and work around it.
- The selected goal (s) can be the foundation to develop a project at a school level with the support of teachers and educators. This is a good way of teaching research, critical thinking analysis, and social responsibility skills. The most urgent mission now lies in turning knowledge into action to address the world's most serious sustainability challenges (Cheng, 2020).
- Socialize the projects and achievement done in schools thanks to the Fortune Teller and SDGs projects by using social media and videos through the power of storytelling using some hashtags: #sdgs #USAforUN #sdgfortuneteller @unasoutherncalifornia
- Scale the model to other schools, neighborhoods, and other entities, such as museums and institutions, in order to advance our agenda for 2030.
- Create videos and tutorials to inspire others and spread awareness of the 2030 agenda. The charts 1- 4 show the method adopted in some institutions in Southern California when introducing the SDGs and using the SDG Fortune Teller. The institutions use a quarter system that has 10 weeks.

Charts 1- 4 summarize the SDG Framework to use the SDG Fortune Teller.

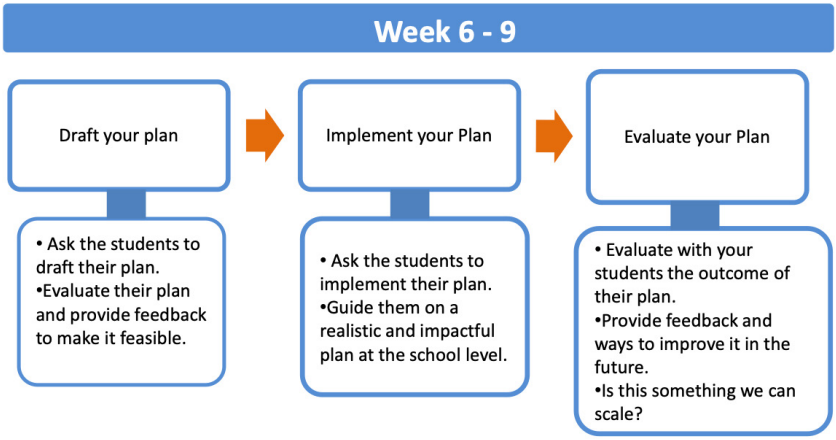
The chart 1. Framework to use the SDG Fortune Teller week 1- 2



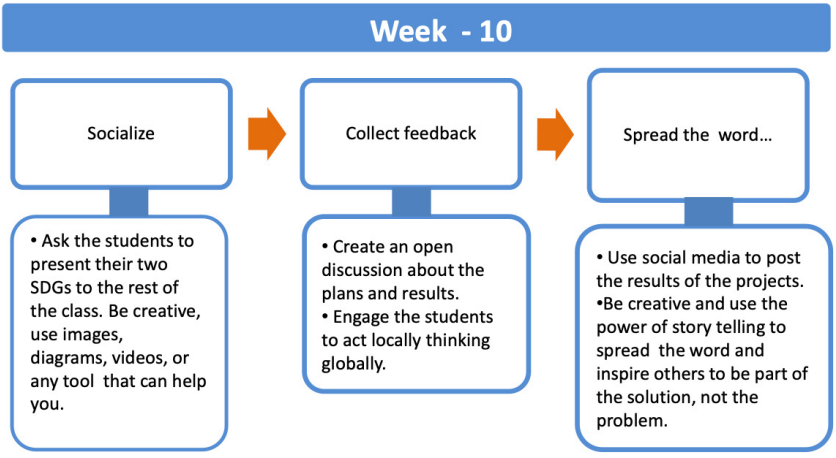
The chart 2. Framework to use the SDG Fortune Teller week 3- 5



The chart 3. Framework to use the SDG Fortune Teller week 6- 9



The chart 4. Framework to use the SDG Fortune Teller week 10



Document the results, including the institution, number of students, age of the participants. We want to evaluate the impact. Do the students remember the SDGs? How were the outcomes of the local plan activity? Did you receive any feedback from the students, parents, or any stakeholders? Collaboration is key. Socialize with other educators who

are teaching the SDGs to get a better idea of how to reach this agenda and share your students' plans as well.

Be active in supporting your student's passions and guide them when they are researching and creating their plan for the two selected SDGs. Guide them on a plan that is impactful, realistic, and workable, but also think big. Contemplate the idea of a plan that can be scaled into other classrooms locally, regionally, nationally, and even worldwide. Remember, this agenda requires the work of everyone on all levels and your work is crucial and valuable to achieving the goals.

Finally, the SDG Fortune Teller is a tool that can bring us closer to achieving the SDGs. This tool has the potential to generate awareness, remembrance, but above all concrete actions. In the United States, it has already permeated homes, sparked dialogue, and led projects around the 17 Sustainable Development Goals in Southern California. Colleges and Universities such as Santa Ana High School, Heritage High School - Orange County, West Coast College, SOKA University, Fashion Institute of Design and Merchandising and UC Irvine to name a few, have already used the SDG Fortune Teller (Figure 5).

Challenges and recommendations

A challenge encountered when creating the tool was to introduce it properly; however, in 2016, the tool was presented to a large audience at the Ronald Reagan building and International Trade Centre in front of over 800 people during the Leadership Summit of the United Nations Association. Many chapter leaders of the association took the tool home and started working with the English version. Another challenge was to distribute the tool physically. Thanks to a donor in Los Angeles, it was possible to print out over 1,000 SDG Fortune Tellers in the U. S and South America.

Figure 5. SDG Fortune Teller users

Other challenge has been finding more channels of communication. The idea is to bring the SDG Fortune Teller to more people, by tapping into more collaborations. A recommendation is to find more partners that can benefit from it and believe in the agenda's importance. In this order of ideas, the SDG Fortune Teller has been introduced to the Global Network for Sustainable Development (GNSD) during summer 2022 and by Fall 2022, the idea is to work actively, as the goal is to teach youth

about sustainability using the principle of "learning by doing". The GNSD implements its mission by creating sustainability and Peace Clubs in schools. Members of these clubs can be involved in local community projects, as well as in the Sister Schools Project, creating partnerships between schools in different countries. The plan is to create 20 such partnerships between schools in Ukraine, Poland, Nepal, India, and the USA (GNSD, n. d). With this in mind, the tool is now being translated into Ukrainian and Hindu; however, Bengali needs to be introduced as well considering the number of speakers which is actually 265 million speakers (Bangla ranked at 7th among 100 most spoken languages worldwide, n.d.) and finally, Polish, and Nepali, also called Gorkhali will be added to the languages considering the GNSD potential partnership.

Conclusion

To conclude, it is important to highlight that the SDGs are not just another framework for governments and nonprofits to drive popularity and engagement; but it is critical to understand that the 2030 agenda reflects the needs of governments, the private sector, NGOs, academia, and civil society's necessities. The SDGs are rooted in basic pillars for economic, social, political, and environmental development with a common axis around nondiscrimination, equity, and human rights. Hence, it is an ambitious and robust approach because it defines and reflects us as developing and complex creatures. It is easy to fall into the tendency of complaining about what is not working, but yet; we forget our role in bringing solutions. To execute a plan, it is key to have both a blueprint and a map; the SDGs are exactly that. So, in order to address complex problems, we need a holistic approach with thorough solutions involving everyone on all levels and all corners. The path to reach the 2030 agenda has been challenging, and the pandemic added an extra layer by disrupting the advancement and slowing down progress around the 17 goals. One sector won't be able to fulfill the agenda and reach

all the goals. Synergies are important and education is strategic to not just cultivate skills in students, but to also grow mindsets and develop positive and sustainable behaviors through ESD. That is why instructors and professors are pivotal agents supporting the future designers and future generations that will lead and shape society, while protecting our planet and respecting each other. The SDG Fortune Teller provided an easy and engaging tool that promotes creativity and curiosity by fueling deep learning. The goal is to turn passions into actions by learning the agenda, selecting a goal, and working on realistic projects around the 17 goals. The ultimate scope is to think globally, act locally and the SDG Fortune Teller is a good start. In the U.S., the SDG Fortune Teller has permeated some schools, homes, and institutions, but the 2030 agenda needs more and better channels to spread the message and engage everyone. Finally, the recommendation is to create more tools and methodologies to support the SDGs. We cannot afford another pandemic or WWIII to understand that united we achieve more, by working together we can bring the best of each other every day, and eventually will create impactful, lasting change collectively.

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Education for sustainability in creative disciplines at Universidad Pontificia Bolivariana, Universidad de Medellín and Institución Universitaria Pascual Bravo at Medellín – Colombia

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Abstract

The university plays a decisive role in the training of environmentally responsible individuals, which is why it has the obligation to include sustainability in its curricula, so that future professionals develop their work from a sustainable perspective, which leads them to act responsibly

and committed to their immediate environment. The process of integrating universities' education, research, operations and external facing activities to contribute to the achievement of the Sustainable Development Goals—SDG (SDSN, 2017) is difficult and involves a profound transformation of the educational model. This paper explores differing approaches and strategies to sustainability education in creative disciplines, their effects on student awareness towards sustainable development, assessing design and architecture curricula in three Higher Education Institutions in Medellín, Colombia. These are: Universidad de Medellín, Universidad Pontificia Bolivariana and Institusión Universitaria Pascual Bravo. The three institutions use different sustainability education approaches.

Keywords: SDG4, Education, Sustainability, Creative Disciplines

Introduction

The SDG 4 in target 4.7 states that "By 2030, ensure that all learners gain the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence (...)" (UN, 2016), a goal that can only be achieved by transforming the skills and competencies that future professionals are expected to gain.

The project Education for sustainability and professional training in creative disciplines analyses the importance of incorporating sustainability criteria and guidelines into the higher education curriculum of disciplines such as design and architecture, as an essential component in the training of future professionals. The study focuses, in particular, on the training of students of clothing, fashion, product, graphic design and

architecture at different levels, through their immersion in the culture of sustainability, so that they can contribute as responsible citizens prepared to take part in decision making, to propose informed actions and solutions to the socio-environmental problems, and transform consumption and production practices.

This is an initial study of approximation to the field of education for sustainable development (EfSD) in Colombian universities, and because of the research problem, it is considered a qualitative approach of interpretative cut on an intentioned and reduced sample of programs.

Literature review

Education for Sustainable Development and Sustainable Learning Education

Traditional teaching methods offer students a cognitive understanding of sustainability issues but lack the holistic point of view, the diffusion of sustainability as a topic has outpaced the diffusion of tools to train future designers and architects to move beyond the largely settle a matter of awareness of these challenges creating effective solutions (Boarin, P. et al. 2020). Cotton and Winter (2010) state that a philosophical review of the concept of sustainability reveals that teaching sustainability is complex and requires different approaches. This is because sustainability as a concept requires context and subjectivity, traditional pedagogies based on positivist epistemology and instrumental ideology are inadequate to explore its complexity (Christie, B. et al., 2013).

Education for Sustainable Development (ESD) is an integral element of the 2030 Agenda, in particular Sustainable Development Goal 4 (SDG 4), and a key enabler for the achievement of all other SDGs. Although

ESD was first detailed at Agenda 21 (1992) (four major thrusts: 1. improve basic education, 2. reorient existing education, 3. develop public understanding, 4. Training); then at 1998, UN Commission on Sustainable Development (CSD) made an agreement on the essential role of education at sustainable development; UNESCO recognized at Education for Sustainable Development in Action Learning & Training Tools (2006) that "Progressing from the global concepts of ESD to locally relevant curriculum is a difficult process" (2006, p.25)

The Berlin Declaration on Education for Sustainable Development (2022) is a recent and important document that highlights the significance of ESD for humanity. It emphasized on the importance of:

Ensure (ensuring) that ESD is a foundational element of our education systems at all levels, with environmental and climate action as a core curriculum component, while maintaining a holistic perspective on ESD that recognizes the interrelatedness of all dimensions of sustainable development (p.3)

Implementing ESD with joint emphasis on the cognitive skills, social and emotional learning, and action competences for individual and societal dimensions of transformation, promoting individual behavioral change for sustainable development, equality and respect for human rights, as well as fundamental structural and cultural changes at the systemic level of economies and societies; and also promoting the required political action to bring about these changes (p.p.3-4)

Continuing the work with the United Nations Decade of Education for Sustainable Development (2005-2014) and the Global Action Programme (GAP) on ESD (2015-2019), today UNESCO is leading the Education 2030 Agenda, which is part of the commitment to accomplish the 17 Sustainable Development Goals by 2030. Education aims to ensure inclusive and fair quality education and promote lifelong learning opportunities for all.

The SDG 4, target 4.7, calls for development of skills and knowledge "through education for sustainable development and sustainable lifestyles" (United Nations 2015a). While the SDG Goal 4, Target 4.3, calls for ensuring equal access for all women and men to affordable and quality technical, vocational, and tertiary education, including universities around the world by 2030 (United Nations 2015b); the SDGs lack targets that would make this a reality in many low-income countries, where higher education requires reform and rebuilding. Instead of aiding these countries to (re) build and strengthen their fragile higher education systems and institutions, the SDGs, as expressed in Target 4.7, seem to aim only to provide opportunities to a selected group of individuals to study at universities in developed and some developing countries. This approach has failed in the past and will only lead to the creation of dependency on foreign aid and help, and the continuation of chronic lack of capacity in many low-income countries.

In Colombia, the Ministries of National Education and of Environment, Housing and Territorial Development in Colombia have been working since 2005 in strategies for including the environmental dimension in formal education based on the national educational and environmental policies, and the formation of an ethical culture in the management of environment, through the definition and implementation of School Environmental Projects (PRAE, for its acronym in Spanish).

The PRAE are pedagogical projects that promote the analysis and understanding of local, regional and national environmental problems, and generate spaces of participation to implement solution accordance with natural and socio-cultural dynamics. The focus of their work is training form a conception of sustainable development, understood as the use of resources in the present, without detriment to their use by future generations, with spatiotemporal references and based on respect for diversity and autonomy, and that contemplates not only economic

aspects but also social, cultural, political, ethical and aesthetic aspects in favor of a sustainable management of the environment.

These projects provide spaces in the school for the development of research and intervention strategies. The former involves pedagogical-didact and interdisciplinary processes, whose purpose is to critically reflect on the ways of seeing, reasoning and interpreting the world and the ways of relating to it; likewise, on the working methods, the approaches to knowledge and, the vision and interaction between the different components of the environment. The second intervention involves concrete actions of participation and community outreach.

The school works together with the environmental sector, with social organizations interested in the subject and with the community. In this way, the school can show its guiding role and open spaces for the self-regulation of citizen behaviors required for environmental sustainability. PRAE projects are examples of Education for Sustainable Development in Middle and High school, some methods and tools used in these projects may be replayed in Higher Education Institutions for the training of future professionals.

Previews research draws a blueprint of the different focus of implementing sustainability teaching in Higher Education Institutions around the world (Boarin, 2019; Cotton, D and Winter, J, 2010; Xiang, X, 2021; Christie, B et al., 2012). Boarin and coauthors reference different approaches to integrating sustainability in design and architectural programs have been implemented. “Some of these initiatives have been successful by involving sustainability aspects of existing courses, creating new sustainability-specific courses, and activities to improve students´ sustainability awareness” (2019, p. 3).

The following sections will show different approaches to sustainable development education and their application into design and architectural curricula in Higher Education Institutions like SLE and

Sustainable Learning Education (SLE)

According to Hays and Reinders (2020), the intent of Sustainable Learning and Education (SLE) is to create and proliferate sustainable curricula, methods of learning and teachings that instill the skills and dispositions to thrive in complicated and challenging circumstances, and to contribute positively in making the world a better place. What makes SLE different from other pedagogical approaches or educational theories is its focus on sustainability, self-sufficiency, and consciousness. According to Stroh (2015), SLE overcomes the insufficiencies of a replication of solutions and incremental learning.

Facing the urgent requirements of The Global Education 2030 Agenda, a new paradigm for learning and teaching is required, since current models do not contribute to the required technological and social transformation, are ineffective and, according to Hays, 2017, may even be counterproductive. The author recognizes SLE as an "emerging and timely concept—a reimagined and re-engineered system of and for education and professional development" (2017), and suggests that SLE embodies the pillars of sustainability integrating them into the learning and educating process.

From this concept, with a constant exercise of bibliographic exploration, the team of researchers questioned how professional training programs in Colombia have integrated these pillars in their curricula, contributing to the achievement of the sustainable development goals, especially in programs of creative disciplines in the city of Medellin. Within this context, the exploration and review began.

Sustainable design and architectural education

The major tasks of sustainable design and architectural education are to teach students the concepts of sustainable development and knowledge of sustainable design (architectural, product, clothing and graphic), and to train them to incorporate sustainable technologies into their projects. (Álvarez, S.P. et al., 2016). As Xingwei Xiang and colleagues argue on their paper, A Pedagogical Approach to Incorporating the Concept of Sustainability into Design-to-Physical-Construction Teaching in Introductory Architectural Design Courses: A Case Study on a Bamboo Construction Project (2021), combining architecture design education and sustainability is commonly found in intermediate and senior years, as well as in higher degree programs.

Method

Qualitative methods such as bibliographic analysis, semi-structured interviews, and participatory observation were used. The objects of study in this paper are Curricula and SDGS in Colombia, especially Medellín. Relevant papers published in Scopus and Web of Science were reviewed, databases used for archiving scientific papers. The search string was intentionally designed to provide reasonable coverage of the diverse research that exists on Curricula, Creative Disciplines, Education for Sustainability and SDGS.

An online five question questionnaire was sent to approximately 700 students of creative disciplines, in the three institutions, on 18 of September 2021 (contact details for academics and students were retrieved by the academic secretaries of each institution), and 15 semi-structured interviews were conducted with faculty professors and administrative staff.

Questions provided a “snap shot” of current teachings and education on sustainability practices across creative disciplines, and were based on the SDG 4 target 4.7 literature. Analysis grids were constructed for the comparative study of the capacities and competencies of chosen professional training programs of the Universidad Pontificia Bolivariana, Institución Universitaria Pascual Bravo and Universidad de Medellín, all Higher Education Institutions in Medellín, Colombia.

Results and Discussion

Data Collection

The data collection for this research took place in July - November 2021 at the UPB, UdeM and I.U. Pascual Bravo and was primarily focused on creative disciplines curricula among the three institutions.

Initially, a literature review was made to attempt the categorial frame that supports the research. With this, a next stage of a comparative study was performed, searching and correlating capacities and competencies of chosen professional training programs; analysis grids were constructed and used, enabling the identification and recognition of the commonplaces and the particular ways of assuming sustainability in each training program.

Besides the literature review and comparative study previously made, the data collection was performed through two instruments: an online questionnaire designed to collect student’s perspectives, and a protocol for semi-structured interviews destined to get a profound insight on professors’ discourses related to sustainability. Using every instrument is described next.

Analysis Grids

A comparative study of the capacities and competencies of the professional training programs of the chosen Higher Education Institutions was conducted. Thereupon, analysis grids were constructed in a shared online file, enabling the researchers to look, identify and compare the information that every institution shared from the syllabus and curriculum of the chosen programs. The following is a preview of the grid elaborated and filled for the researchers.

Researchers draw some conclusions comparing information for the grid that shows the different approaches to sustainability and the multiple pedagogical and educational strategies in the three institutions.

UdeM: the commonplace in the syllabus where the word sustainability is found or directly referred to, or one component reviewed, is in the management courses, where students are expected to develop business models consistent with the principles of sustainability. The recognition of the context, requirements and problems appears in several competency criteria; although it is difficult to determine how often such problems correspond to those stated in the SDGs or the variables analyzed here. It is noteworthy that the techno-productive component, responsible for the training in the different productive and material processes, there is no explicit reference to impacts on the environment.

I.U. Pascual Bravo: within the review, concepts alluding to sustainability, sustainable design or sustainable development are noticed. The importance of approaching and applying practices that contribute to sustainability is recognized. Regarding the Interdependence component, only in the Human Development subjects the tools that allow the measurement or sign of impacts on human life against the ecosystems are recognized; in fact, it is the only course that directly

Figure 1 Analysis grid for comparative study of capacities and competencies of professional training programs of chosen Higher Education Institutions.

PROYECTO EDUCACIÓN PARA LA SOSTENIBILIDAD																					
Matriz para la evaluación de variables de sostenibilidad en cursos de disciplinas creativas																					
30/8/2021																					
Universidad:																					
Analizó:																					
												Herramientas para medir: huella de carbono, impacto ambiental...									
Nombre del curso	Tipología	Programa	Nivel o ciclo	Objetivos de desarrollo sostenible	ODS 2	ODS 3	Recursos curriculares y/o tecnológicos	Leyes, acuerdos y/o políticas	Situación local o regional	Mejores prácticas empresariales o sociales	Cultura de la sostenibilidad	Interdependencia	Diversidad	Derechos humanos	Equidad y justicia	Derechos generaciones futuras	Conservación	Vitalidad económica	Democracia y participación	Principio de precaución	Estilo de vida	Observaciones

Elaborated by Research Team. 2021.

raises the importance of the SDGs in the elements of the competence to be developed.

UPB: clothing design programs present multiple competencies related to sustainable development in its descriptive letters. From the invitation to students to problematize and research the context from social, cultural, economic and environmental terms intended to manage contextualized and viable projects; the development of proposals that consider their productive, economic, environmental and social viability; the analysis of the socio-cultural, environmental and economic-productive implications of the garment product already made, and finally; the reflection on the traditions, practices, emergencies, and phenomena related to clothing and apparel. Considering the above, it can be said that this program conceives sustainability as a transversal axis of the curriculum, which impacts not only some courses, but becomes an end present in most of the training spaces.

Questionnaire

The questionnaire instrument used as an approach to understand the student's perspectives was designed looking for simplicity and clarity to get answers. Only five questions of multiple-choice selection were included. First, second and third questions were made to identify the university's affiliation; fourth and fifth allowed for several alternatives to be selected, and were made asking specifically about sustainability topics. Questions are related:

1. University where you study
2. Academic program you are enrolled in
3. Which semester are you in?
4. Show the topics about which you have received SUFFICIENT information for your professional development:

- Sustainable Development Goals (SDGs)
- Bibliography, materials, processes linked to sustainable development available at your University.
- Laws, agreements and/or regional, national and international policies related to sustainability
- Local or regional situation linked to consumption and/or environmental protection
- Best business or social practices in terms of sustainable development
- Ancestral, indigenous, or native knowledge related to the diversity, care, protection and opportunities of natural resources.
- The impact of your designs on relationships between people, or their impact on the environment.

5. Point out the topics that you could discuss and/or debate SUFFICIENTLY:
   - The interdependence between people and the environment
   - Cultural, economic, social, biological diversity, etc. and the need to protect it
   - Your rights and duties as a human being
   - Your responsibility as a professional to contribute to a fair and fulfilling life of others
   - Your responsibility towards future generations is to guarantee their access to natural resources.
   - How your lifestyle can affect the availability of limited and renewable resources in the future
   - The need for everyone to develop skills and abilities to achieve a satisfying and sustainable life
   - The participation alternatives to which you are entitled.
   - Who to turn to make informed decisions about the impact of your projects on the environment
   - Alternatives that allow you to have a more sustainable lifestyle

The survey received answers from 658 students from the three mentioned universities within 12 academic programs related to creative disciplines. 42.7% declared that they were in the middle of their professional curriculum, 31.5% of students were just starting and 25.8% are finishing.

Some of the most significant data got are:

Semi-structured interviews

In order to know the professors' perspectives, 15 semi-structured interviews were conducted with five faculty professors at each university. Researchers questioned professors on how they incorporate the SDGs and apply them in their courses, opting for a semi-structured protocol that allows open spaces for profound dialogues.

The guiding questions for the conversation are:

- In what ways do you incorporate the SDGs and apply them in your courses?
- What strategies, teaching resources, and classroom exercises do you use in your courses to teach sustainable development issues?
- What strategies do you apply to implement a culture of sustainability in students?
- The interviews were recorded and transcript afterwards. From there, it was possible to make discourse analysis, emphasizing on the pedagogical strategies described.

Some of the most repeated words in the interviews were:

- Sustainability
- Project Consumption
- Territory

- Research
- Impact
- Technology
- Industry
- Responsible
- Strategies

Some of the most relevant topics that emerged during these meetings were:

- Context problems
- Reality principle
- Discourse
- Sustainability (Sostenibilidad vs. sustentabilidad)
- Hidden curriculum
- Student participation
- Questioning of consumption habits
- Interdependence
- Alternatives
- Entrepreneurship
- Critical thinking
- Student as a citizen
- Concept of viability
- Three pillars: economic, social, and environmental.
- About ODS: responsible production and consumption, equity, equality related to the ergonomics theme.
- Life, ethics, aesthetics
- Training for environmental and cultural sustainability
- Qualification of teachers (so that rubrics can incorporate evaluable aspects in the professional cycle)

Aside from over impact on students´ views of sustainability which might be attributed to curriculum and pedagogy, students are also

affected by what it is known as “the hidden curriculum” (Jackson, 1968). This incorporates the massages sent by an individual tutor or an institution, often unconsciously and covertly, to students about hoy they ought to think and behave. A key way in which the hidden curricula is made manifest is through the values of the institution, there is also potential for individual lectures´ believes, as seen in the semi-structured interviews, to influence both the content and the structure of the curriculum.

Teachers interviewed, suggest that tutors actually influence students in ways well beyond the classroom or the subject, for example, by choosing texts and cultural products, commenting on their structure or contextualization, but also providing pawns for discussing issues of sustainability, climate change and ecological justice.

We considered that is important to have a critical awareness of the different ways in which the hidden curriculum might be at work both within and beyond the classroom is essential to understand the impact of teaching about sustainability in creative disciplines. Drawing from the experiences described by the teachers in the three institutions, we may derive some strategies in two groups.

First, addressing wicked and real-life problems, identifying contemporary tensions which will help students recognize design problems in their environment and place them within the goals of sustainable development, and visualize the complexity of these problems and tensions identifying them as “wicked problems” (Kolko, 2012, Buchanan, 1989). Once this analysis is done, students are motivated to recognize the relationship between the global problems they have analyzed and the community. This reflection also serves as a personal evaluation criterion for their own design exercises in this and in other courses (Vélez - Granda, 2021). Students learn to understand the relationship between people, technology and the environment in multiple scales of relation.

Second, strengthening multidisciplinary and multi-actor approach to environmental and socio-cultural aspects involving local stakeholders, communities, teachers and students into collaborative and co-creative work. All these through understanding and studying real-life examples of use and reuse, recycled raw materials, the use of organic fibers, or collecting materials for recycling or reuse. The interviewees agree that this approach and teamwork extend the limits of design and architectural training towards working with complex socio-cultural, socio-economic and socio-technical systems that may lead to versatile understandings of sustainability.

Conclusion

Although the adoption of pedagogies and teaching methods advocated for Efs, SLE and SDG 4 is low, there is evidence that professors at the three institutions are actively seeking to make their lessons more interactive and innovative. Professors apply tools and methodologies to promote sustainable design and architecture under their own expertise, but very few of them are explicitly declared in the curricula from every training program.

When students approach projects related to genuine issues of living, they commit to doing the best they can in terms of sustainability and the impacts of their proposals. A sustainability strategy for the pedagogy of creative disciplines is needed, recognizing designers as problematizers, with context awareness, and an as agents of change and transformation.

Overall, field explorations, collaborative design, analysis of wicked problems, while not a new pedagogical approach, are worth becoming an essential part of product, graphic and industrial design and architectural education. For both teachers and students, integrating field study into the curriculum permanently would allow transferring the traditional ideating-

making-reflecting activities from the studio into a real-life setting. Also, the wide analysis of real-life and wicked problems integrated into the curricula would allow a strong transformation in design and architectural projects.

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The Universidad Pontificia Bolivariana and its commitment to sustainability education

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Abstract

The University, from its strategic orientations, considers that the generation, strengthening and consolidation of capacities associated with sustainability should be a determining factor in its organizational culture in its projection challenges, so it should be assumed as a priority that implies facing a model that considers that the relationship between sustainability, innovation and knowledge management does not arise from spontaneous and unsystematic connections, but from deliberate actions that favor the coherence of processes considering cultural, economic and context situations to get results that generate impact and transformations in its employees and other stakeholders.

Keywords: UPB Sostenible, Strategic orientation, Education

Introduction

The University, from its strategic orientations, considers that the generation, strengthening and consolidation of capacities associated with sustainability should be a determining factor in its organizational culture in its projection challenges, so it should be assumed as a priority that implies facing a model that considers that the relationship between sustainability, innovation and knowledge management does not arise from spontaneous and unsystematic connections, but from deliberate actions that favor the coherence of processes considering cultural, economic and context situations to get results that generate impact and transformations in its employees and other stakeholders.

To achieve the transition between these models, it is necessary to channel and articulate efforts towards a process of awareness, education and application in the areas of sustainability, innovation and knowledge management that favors that all members of the university community incorporate in their daily actions the premises of sustainable development in their life project and contribute consistently with the competitive platform of the UPB Multi-campus, which integrates the headquarters in the city of Medellin and the sectional offices in Monteria, Bucaramanga and Palmira, as well as the territories where we are present throughout the country. The general purpose of the "Sustainable UPB" strategy is to achieve the transformation of attitudes and practices at all levels of the University so that they permeate the culture and thus understand that sustainability is rarely a product of chance and that in order to achieve it, rigorous, consistent and human-centered work is required as a principle of action.

In recent years, in response to global concern about the pressure on natural resources and the social affects of excessive economic growth, various conferences, meetings and agreements have been

held to take actions aimed at sustainable development, and although progress has been made in this area, non-binding policies have hindered implementation. However, in the challenges posed in the year 2000 through the Millennium Development Goals MDGs [1] and recently in the Sustainable Development Goals SDGs [2], concise goals have been set for the latter to be achieved by 2030.

Under the Encyclical Letter of the Holy Father Francis "Laudato Si" 050 [3] on the Care of the Common Home in May 2015, a call is made to humanity to realize the need to change lifestyles, production and consumption, besides recognizing that in recent decades much of the environmental changes such as global warming is caused by human activity. Likewise, Pope Francis "makes an urgent invitation to a new dialogue on how we are building the future of the planet and the need for a conversation that unites us all, because the environmental challenge we are living, and its human roots, interest and impact us all" [3]. In this sense, the University has a fundamental role in the education for transformation and the promotion and implementation of measures oriented not only to the adoption of sustainable lifestyles but also to the transfer and generation of technical knowledge that tends to the innovation of a closed-cycle economic model [4].

Throughout its 80 years of existence, UPB has had as one of its guiding principles the positive impact on each of the dimensions of what today is called sustainability. In the aspect of its structure, the institution has generated a series of policies that have been aimed at promoting the welfare of its stakeholders: employees; students; users of research and transfer, among others.

During the rectorship of Monsignor Luis Fernando Rodríguez Velásquez, there were two crucial milestones for the University: from the Pastoral Vice-Rectory, led by Fr. Julio Jairo Ceballos Sepúlveda, the policy of social projection that guided this macro-process was generated;

subsequently, and from the same Vice-Rectory, but headed by Fr. Sergio Alondo Duque Hernández, the social responsibility policy was designed and disseminated, reaffirming the University's permanent commitment to generate impacts that contribute to human and sustainable development. This policy was aligned with the initiatives that occupied the social responsibility landscape: Global Compact, the Millennium Development Goals, the Ethos Institute and the Global Reporting Initiative, GRI.

Currently, the University has made three strategic decisions that make up the three milestones of the moment: forming the Strategic Sustainability Committee; contextualizing the social responsibility policy within the guidelines of the 2030 Agenda for development led by the United Nations Organization, UN; and delivering the Sustainability Report of the UPB system.

While the topics of social responsibility and sustainability have been present in UPB throughout its history, what is presented now is an inclusive institutional initiative to contextualize them in the current development referents always in tune with the substantial referents that provide its identity.

1. The sustainability strategy

The Pastoral Vice Rector's Office, aware of the challenges and opportunities that sustainability issues represent for the University, assumes the leadership of the strategy called "UPB Sustainable" understood as a process of generation and consolidation of human-centered capabilities and from which the environmental, economic and social dimensions are articulated, economic and social dimensions are articulated, being an increasingly current, relevant and powerful source for its internalization by the entire university community - as a substantive

element of its organizational culture - and is reflected in an impact on stakeholders within the framework of social and human transformation as a higher purpose of the UPB.

In 2017, the sustainability strategy was launched at the Universidad Pontificia Bolivariana and it is in preparing the first sustainability report exercise where the opportunities and challenges that the university has in terms of sustainability become clear. This is the starting point to draw a roadmap (Figure 1) whose primary aim is to identify and propose a series of projects and programs that will be implemented at the Multi-campus level and that also support the strategy. Thus, five programs are born that focus on: i) information transparency management, ii) communication for sustainability, iii) generation and strengthening of capacities, iv) monitoring and follow-up of key sustainability variables, and v) strategic articulation of sustainability.

2. Training for sustainability

Figure 1. Programs and Projects, UPB Sostenible.

Source: own construction.

The capacity building and strengthening program (GenC) seeks to promote theoretical and practical knowledge in relation to sustainable development and sustainable lifestyles proposed in the 2030 Agenda, specifically Sustainable Development Goal 4 "Quality Education" target 4.7. This is divided into three projects: i. Sustainability Chair, ii. External offer of training and services in sustainability and iii. Qualification - training table, which is detailed below.

2.1. Sustainability Chair.

The university has 8 schools in different branches of knowledge: School of Architecture and Design, School of Social Sciences, School of Health Sciences, School of Law and Political Sciences, School of Economics, Administration and Business, School of Education, School of Engineering and School of Theology, Philosophy and Humanities, which offer 73 undergraduate programs, 111 specialization programs, 78 master's degrees and 12 doctorates. After a rigorous process of review of the curricula and the descriptive letters of the various courses offered, subjects were found that have a direct relationship with some of the Sustainable Development Goals, but these addressed sustainability partially and focused on specific areas, which is why the need was found to build a course that would provide the theoretical and practical knowledge necessary to promote sustainable development holistically.

The university, aware of its role as a trainer of professionals who understand the importance of carrying out their work; having the notion that sustainability is a necessity in everyday life and work in today's world; launches a strategy called the sustainability chair for the year 2018, as a proposal to integrate a subject to the Basic Humanistic Training Cycle in all undergraduate and graduate programs; which has been gradually integrated into the humanistic training cycles. The sustainability subject (Figure 2) is supported by four modules that are oriented by the axes

defined by the United Nations Organization (UN), which cover the challenges of humanity included in the 2030 Agenda: people, planet, prosperity, peace and alliances. For its design, national and international references in education for sustainable development were considered, all in line with the global challenges of the UN Agenda 2030 and the strategic references of the UPB as a "teaching university, with emphasis on research and innovation for sustainability".

The sustainability professorship aims to show the historical context of the concept of development that has given direction to the current situation, students will recognize the social, environmental and economic challenges of humanity which require major transformations regarding values and practice in both daily and professional life. UPB generates a direct impact on goal number four of the Agenda for Sustainable Development (2030) of the United Nations; "Ensure inclusive and fair quality education and promote lifelong learning opportunities for all", it

Figure 2. Sustainability Cathedra Modules

is worth noting a specific challenge to which educational institutions are called, and it is related to goal 4.7, which expresses.

Target 4.7 of the 2030 Agenda

"By 2030, ensure that all learners gain the knowledge and skills necessary to promote sustainable development, including through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and the contribution of culture to sustainable development."

Global universities such as Anglia Ruskin University (England), the Gothenburg School of Business, Economics and Law (Sweden), Harvard University, Massachusetts Institute of Technology, Carnegie Mellon University and the University of Pennsylvania (United States), among others, have included subjects focused on the Chair of Sustainability. Likewise, Colombian universities have joined this initiative, universities such as the Externado de Colombia, which in its postgraduate offer includes a subject on Sustainable Development, as well as the EAFIT University, which includes the same subject, but for its undergraduate students within its elective cycle NFI (Institutional Formation Nucleus).

With UPB, the sustainability chair is carried out as a response to global challenges, this in tune with its university model which expresses: "A teaching university, with emphasis on research and innovation", all this hand in hand with sustainability. This initiative has also gone hand in hand with actions that make the university visible to the public, since UPB is part of the "university pact for education for sustainable development" which was carried out by the Mayor's Office of Medellin, besides taking part in international rankings such as UI Green Metric, where there is an indicator that is directly related to the number of subjects that have the environment and sustainability as a theme.

As of 2022, UPB has had some success cases by including subjects related to sustainability and in other cases progress in the adhesion of subjects within the curriculum of several faculties, among the successful cases we can highlight the inclusion of the Chair of Sustainability by the School of Architecture and Design and Economics, Administration and Business in graduate programs in the Eco campus Laureles, another case of success is in the Palmira sectional where the cathedra was included in the CBFH.

2.2. External offer of training and services in sustainability.

At UPB, Continuing Education is understood as a knowledge production strategy expressed in non-degree academic services, which are developed by the Schools and academic units. These types of courses favor the updating, training and formation for the development of skills, abilities and knowledge.

The University has merged an important offer of courses and diploma courses on topics related to sustainability in coordination with different areas of the university, such as Continuing Education, Research Groups and Schools. In addition, under the 2030 Agenda for Sustainable Development and in pursuit of a healthier environment that respects all forms of life, UPB has strengthened strategic alliances that allow achieving positive transformations for society and its relationship with natural resources. With this project, we intend to design a training offer: courses, diploma courses and conferences from the different dimensions of sustainability, supported by the human talent of the same. Likewise, in coordination with the different research groups and business units, we seek to merge an offer of consulting services on environmental, social and economic issues with public and private entities and civil society organizations.

Following the line of sustainability, we can highlight the Diploma in Sustainability for Senior Management - ANDI, which is aimed at companies; for this training course, it is important to emphasize that participants must have some kind of link with decisions that have a direct impact on the course of their organizations. This is born because companies and their stakeholders need information and tools that are at the forefront which allow them to develop a new management vision, which is based on ethical values and solid principles of sustainable development. In alliance with ICONTEC is the Senior Management Program in Sustainability, whose main aim is to promote and help public and private organizations and their technical and managerial teams in the development of a managerial vision based on solid ethical principles and values and the principles of sustainable development.

The Universidad Pontificia Bolivariana has offered four thousand two hundred and twenty (4220) curricular contents contemplated in the curriculum offered in the different sections of the university, on sustainability issues, for the case of the central headquarters - Medellin, the number of courses available was two thousand six hundred and eighty-three (2683), data for the year 2021. The following are some courses offered by different schools of the university, such as Eco innovation Course, Course on Sustainable Development Goals applied to companies and the Circular Economy Course in the School's case of Economics, Administration and Business, regarding the School of Engineering are the course on Sustainable Mobility Plans and the Diploma in Sustainability.

Included in all its offerings, the University has, The House of Happiness which is a program of personal growth that includes courses and activities aimed at people to gain knowledge on issues of general culture, spiritual strength and can develop skills in arts and crafts. For the year 2021, the House of Happiness offered the course of the common care in which environmental and sustainability issues were addressed.

The University in its role as a trainer of actors of change, who generate impacts on the environment where they develop, has not only bet on training students with sustainable awareness from the undergraduate level, which have been mentioned previously, but has a training offer for those interested in further strengthening their skills and knowledge about sustainability. The Master's Degree in Sustainability is offered in agreement between UPB and the Fundación Universitaria Católica del Norte, which involves topics associated with the different socio-ecological systems and thus understand how society and the environment interact, besides identifying potential challenges, risks and impacts. The innovation and adaptation of technology to the demands for sustainable development; the handling and management of natural resources for their efficiency, pollution and waste management are topics aimed at decision making according to the requirements of companies, industry, governmental and non-governmental organizations and public administration.

The master's degree also proposes practical tools and methods based on interdisciplinarity from a systemic approach to analyze the problems of unsustainability of socio-ecological systems at the national, regional and local levels. The applicant's professional undergraduate studies may be in the following areas of knowledge: engineering; architecture, urban planning and related fields; social and human sciences, economics, administration and natural sciences.

2.3. Qualification and training table.

In the University there is a wide academic offer and according to the disciplines, in the different training cycles there are subjects that have a direct relation with some objectives of sustainable development. Since the formation of the Strategic Committee on Sustainability and

the consolidation of the work team, the University is strengthening its capabilities (physical and human talent) in sustainability that can generate an external academic offer to reach different audiences and develop research and consultancy. In the opinion and imagination of UPB teachers and administrative staff, there are paradigms based on diffuse sources that do not always respond to the concepts of sustainability, and this situation leads them to make judgments and adopt unconstructive positions that may hinder the proper functioning of the university dynamics.

It is for this reason that the Qualification and Development of Human Talent Program exists at UPB. Its purpose is to qualify the level of training of the working community and improve their practices for optimal personal, professional and work performance. To achieve this purpose, the Program promotes formal education and continuing education activities with facilitators that legitimize the institutional principles and values; in addition, it designs and programs learning experiences, which will allow the management of knowledge that can be embodied in the production of material and spiritual wealth as editorial creation, better work practices and sharing personal experiences that raise awareness and contribute to the life project of the University employees.

Training Committee

The Universidad Pontificia Bolivariana at Multi-campus level has configured a primary committee (Training Board) that is designed according to the size and structure of each sectional and has the participation of different academic and administrative units. Among its principal functions is to design and update the curricular microstructure of the Program, validate the proposals for modification or the descriptive letters of the training experiences, among others.

Culture Nucleus: course and conversations

The link to the training table has been made through the culture nucleus, which includes the Sustainability Training Course and the Pedagogical Conversations. In the Training's case Course, this is aimed at administrative personnel; for those who take it will show the historical context of the concept of sustainable development that has guided the current situation and recognize the social, environmental and economic challenges of humanity from a context of organizational culture and thus these students can put forward ideas to contribute to local solutions in terms of sustainability from the personal and professional.

Universidad Pontificia Bolivariana, aware of its commitment to the environment and under the certification granted by Icontec as the first University in Latin America and the Caribbean to be Carbon Neutral and Zero Waste, will hold a series of Pedagogical Conversations on Sustainability, in charge of the program of qualification and development of human talent.

In the cycle of conversations, there is a convergence of the public and private sectors in a dialogue with the academy, where ideas will be exchanged to reinforce the commitment of the actors involved and to show the fulfillment of the Sustainable Development Goals.

Sustainability leader

This project seeks to continue the training of administrative and teaching staff of the University who, in the exercise of their work, have some relationship with sustainability and innovation or who are interested in expanding their knowledge in these areas; participants will be trained in fundamental concepts of sustainability and, particularly, in the opportunities to exercise significant favorable changes in each of its dimensions from the daily life of their lives, achieving in them a critical and proactive vision. With this initiative, the university seeks that teachers and administrative employees know the development context that has

guided the current situation and recognize the environmental, social and economic challenges of sustainability that demand transformations and practices from their professional and personal lives.

This course seeks to enhance the unique skills related to sustainability and innovation, such as strategic vision, teamwork and technical rigor, and also aims to strengthen human competencies associated with the transformation of the different environments of society, from different disciplines.

Despite its recent configuration and structure, the topics addressed in this course have had great relevance over the years. The concept of sustainable development emerged in 1987 and, since then, the design of mechanisms and methodologies for its implementation has been diverse and applied in all economic and social sectors. The aim of this course is to recognize these transformations that have given rise to a new form of development and incorporating variables, such as innovation and social impact, in the definition of organizational strategies.

With virtuality, teachers have designed different inputs to ensure the transfer of knowledge on the topics addressed. In this way, there will be presentations, videos, podcasts and rigorous bibliographic material, where the student will be able to actively and dynamically consult the key topics for the development of skills. Likewise, the student must independently develop their own inputs with the guidance of the teacher, which will allow them not only to passively attend the instructions but to be part of the design of strategies, plans and proposals that confront them with their role as a professional and citizen in the work of incorporating sustainability in all their work. All this strategy of Sustainability Leader carried out by Multi-campus.

Training of administrative employees

Regarding the training of administrative employees in the Human Management team, training was provided on the historical context of sustainable development and its impact on the current situation, focused on compliance with the 2030 agenda and institutional work. This with the purpose of establishing a greater understanding of the concept of sustainability from its background to its present forms; management tools were presented in the course, and national and international guidelines on sustainability were identified; strengthening the reflective and critical action of the participants; from the dimensions of sustainability, aligned with the principles and values of Christian humanism for the exercise of personal autonomy and social responsibility as an integral subject.

3. Challenges and conclusions

The University not only proposes to provide training programs and courses for external and internal students, but also to advise on sustainability issues, which is why the rest of the project proposes to create a sustainability consultancy, which is a project that is not yet in execution, however when it is implemented, it is intended to promote the generation of spaces for reflection that allow the unification of the Bolivarians' imaginary in relation to sustainability, in response to global challenges, so that all are replicators, as a contribution to the joint project of the consolidation of the culture of university sustainability. In order to reach administrative and teaching staff, the consultancy includes an opportunity to apply the tools and concepts of sustainability to what to do in the university work environment and the dynamics is designed so that it is the teacher or administrative professional who voluntarily, according to the needs of their context, seeks guidance on the subject.

The sustainability strategy has positioned UPB favorably since it has the certifications in Carbon Neutral and Zero Waste by ICONTEC, which has driven changes in the way of providing education since sustainability

is better known in the university campus by undergraduate and graduate students, as well as administrative and teachers, all this with a wide range of training for UPB public and external entities to the University, which shows the commitment not only with the environment but with the community and the different actors; whether public or private; in sustainability issues.

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Teaching sustainability through materials: bridging circular materials and bio-design for new design curricula

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Abstract

This work presents the pedagogical approach and the outcomes of a course aimed at teaching sustainability through the lenses of materials. The last decade has been crucial to finally reach a mature state of awareness of how the material side of our productions and its poor management is at the base of many environmental problems. Such awareness pushed the emergence of new materials, motivated by the search for more sustainable alternatives and a re-evaluation of biological processes capable of creating materials and artifacts through bio-based and bio-fabrication techniques. The clear environmental crises also

pushed the design field to pay more attention to materials; but to date, for designers, understanding the sustainability of materials and their real impact on life cycle products is still not trivial; new biotechnologies are opening up the possibility for designers to experiment with organic sources and living materials. The academic course described in this study focuses on a didactic method based on a practice-based approach; the students are guided to learn the key aspects that can define a material in a sustainable context, improving their material development knowledge and lab working skills. A learning-by-doing path is developed in three workshops tackling material sustainability with an increasing difficulty and understanding. The learning journey starts with an analysis of local wastes for the development of new DIY circular materials. The second step introduces the living variable of bio-fabricated materials, amplifying the complexity of the project and adapting to nature's time scale. The last step requires a higher understanding of the synergistic mechanisms between biotic and abiotic agents in an ecosystem by exploring bio-receptive materials. These three material approaches have been selected for the design methodologies and sustainability principles they have in common. Using classroom observations and a survey, the authors examined student experiences and perceptions of the proposed syllabus in order to understand its efficacy in terms of the last student's material and sustainability awareness. This educational path has proved to deeply connect the students with materials' life cycles and local and natural resources, gaining a deeper understanding of regional environmental issues potentially having a material design solution.

Keywords: Sustainable materials, DIY-Materials, bio-fabrication, bio-receptivity, new design curricula.

The central role of materials in sustainable design

In the last decade, there has been growing attention to the material aspect of our lifestyles and our economies, and this was also reflected in the design field with increased attention to materials. While recent studies pointed out the inadequacy of the management, we have of the planet's resources (Circularity Gap Report, 2021), and how our production methods are still projected towards linear growth models on a finite planet (Elhacham et al., 2020); on the other side, the paradigm of circular economy (CE) has highlighted the central role materials play in an ecological transition (Ashby, 2021). The constantly developing discipline of eco-design (Ceschin & Gaziulusoy, 2016) has often highlighted the central role of materials (Michael F., 2016; Vezzoli, 2013); however, materials' environmental assessment and selection is not a trivial activity for designers, still lacking the right tools to manage material awareness within the project life cycle (Pollini & Rognoli, 2021a). The need for reasoning about sustainability from a material perspective seems urgent and effective at the same time. Materials are in the spotlight in the design practice: they are questioned, assessed for their sustainability, substituted with less impacting solutions, they even become more and more the subject of the design practice itself, for example, through experimental and explorative activities aimed at finding new material solutions with a DIY-Materials approach (Ayala-Garcia & Rognoli, 2017; Rognoli et al., 2015). The hands-on experimentation characterizing this approach for the development of new materials enact tinkering activity, a recognized educational practice grounding on experiential learning, from Bauhaus's didactic notion of learning by doing (Wick, K., 2000), to the more recent phenomena of DIY-Materials (Parisi et al., 2017). In the last years, the will to experiment with materials has been both a bottom-up phenomenon and an educational approach (Pollini & Maccagnan, 2017); designers have felt the need to criticize the choices of conventional materials for

products, willing to better understand the production processes behind them and, as a counterpart, also redesigning them, creating new material possibilities, to open up future scenarios of more circular productions. This approach has been recognized as fundamental in material education since it allows to develop solutions at an intuitive level (Ziyu Zhou, 2022); through practical work with materials and tinkering, students can achieve what is called tacit knowledge, essential for design skills and to collaborate in multidisciplinary environments (Rust, 2004).

New sustainable opportunities arise for designers willing to experiment with materials, given by the recent democratization of science, in particular in biotechnologies. A DIY approach (and open-source philosophy) also characterizes the origin of Biodesign, a nascent hybrid discipline described for the first time in the homonymous book by Myers in 2012 as an "approach to design that draws on biological tenets and even incorporates the use of living materials into structures, objects, and tools" (Myers, 2012). In this design approach, materials gain a predominant role, being made of, with, or from living organisms (Ginsberg & Chieza, 2018), such as mycelium, bacteria, or algae, to name the most experienced ones in the bio-design field. Such bio-fabricated materials (Lee et al., 2020) are often claimed to be sustainable, stimulating a very interested audience (including both design academies and the market), thanks to the sustainable features associated with biological origin and bio-fabrication techniques (Camere & Karana, 2018; Esat & Ahmed-Kristensen, 2018).

Sustainability is, in fact, one of the primary triggers bringing designers closer to this discipline (Collet Carol, 2013; Ginsberg & Chieza, 2018; Oxman, 2010). The many sustainable features of biomaterials justify this aspect (e.g., fast renewability, processes that require little energy, water, and resources, life-friendly chemistry), although the life cycle assessment data for bio-fabricated materials are still few, given that many of them are still on a research stage and under development. However, bio-

fabricated materials show potential also from a circular economy and bioeconomy perspective, not only for their organic origin but also because some of these organisms can be fed on agricultural waste, as showed both by mycelium-based materials (Meyer et al., 2020), and bacterial cellulose (Provin et al., 2021; Puspitasari et al., 2021) productions. In bio-design, materials that grow while alive provide the designer with unusual outcomes; the design process is highly influenced by the role and behaviour of the organism, affecting the tinkering activity, which became here bio-tinkering, taking the meaning of tinkering with materials of biological origin (Rognoli et al., 2021). Of course, the livingness affects this practice by adding non-linear outcomes (Figueroa & Carolina, 2018). Still, it also brings the abilities of life: consciousness, sensory abilities, and responses to external stimuli, adaptability, growth, change. All these aspects are peculiar to the living organisms, which become potent agencies affecting the design process in terms of its performance and aesthetic. Livingness (Elvin Karana et al., 2020) is not the only quality to be considered in the design process. From a bio-design perspective, inert materials support the living; therefore, the inert counterpart needs to be designed for the organism's requirements and the environment in which it is located. The importance of inert materials in bio-design have been highlighted in a recent study that expanded the definition of bio receptive design, suggesting its involvement "every time a material/artifact is intentionally designed to be colonized by life forms" (Pollini & Rognoli, 2021). Some material features, such as colours, porosity, composition and shape, can welcome living organisms, like lichen and mosses, algae, insects or mussels. These inert/alive assemblages can remediate polluted environments, increase biodiversity in depleted zones, or boost cities' biophilia (Söderlund, 2019). Bioreceptive materials can serve as a nursery for organisms able to positively interact with their environment; for example, MARS[1], a 3d printed ceramic modular structure, has been

[1] Retrieved 6 April 2022, from https://www.reefdesignlab.com/mars1

colonized by corals to restore damaged reefs; another example is H.O.R.T.U.S[2], designed by EcoLogic Studio and claimed to be the first 3D printed bioreactor, hosting algae and cyanobacteria for interiors air purification. Even though this approach is still a niche in design, the growing interest in living materials in the biodesign field makes the design of inert materials' bio-receptivity an essential counterpart to sustain life forms, while giving the designer the possibility to design for small scale living ecosystems, assemblages of inert and alive materials.

How to learn sustainability principles through materials hands-on experimentation

The three emerging material trends discussed so far can also be evidence that such materials experiments have pushed designers towards greater environmental awareness. The development of DIY-Materials forces designers to focus on sources, materials flow, and the expressive-sensorial potentials (Ayala-Garcia & Rognoli, 2017) of new materials derived from waste, supporting their applications in design. Designers, tinkering and creating new materials fully understand their life cycle, the input and output of the manufacturing processes, and their end-of-life potential. Besides this, an approach such as the Material Driven Design method (MDD), developed to facilitate designing for material experiences, is often associated to the DIY-Materials, since it helps to unveil the material's features to enable envisioning accordingly its applications (Karana et al., 2015). This approach brings a transition from a form-focused to a material-focused design process, which can help the designers make sustainably informed decisions in terms of material processing, finishing, and application; to where it is possible to talk about MDD for sustainability (Bak-Andersen, 2018). MDD can also apply to

[2] Retrieved 6 April 2022, from https://www.ecologicstudio.com/projects/h-o-r-t-u-s-xl-astaxanthin-g

bio-fabricated materials (Parisi et al., 2016; Zhou et al., 2020); here the designer experience a closer collaboration with living and responsive organisms, capable of growing and giving life to renewable, biocompatible and circular materials and objects. With bio-receptive materials, providing a solid perception of the complexity of ecosystems and places, their design implies a deep understanding of the balance between different agents inhabiting a shared space. The authors, confident that these design approaches needs to be experienced hands-on to activate the intuitive and tacit knowledge leading to a deeper understanding of materials' environmental potentialities and implications, are presenting here the structure and the results of an elective course based on the hypothesis that sustainability principles can be taught through the lenses of materials. By experimenting with local and wasted sources, the students can map new local possibilities for circular materials by practically experiencing their life cycles as they try to create them. Dealing with and for living organisms (both living materials and bio-receptive ones), students need to face the dynamic abilities of life, eventually developing feeling of empathy and care (Camere & Karana, 2018; Keune, 2021); they can directly observe the growth of the materials, see their responses and behaviors to the environment they are exposed, learning about the physical and environmental parameters needed to co-design with the living. Trying to develop a bioreceptive project, aiming at its restorative potential, also gives students a sense of the ecosystem's dynamics and the relationships between biotic and abiotic in a system. The pedagogical approach suggested in this work aims to build a deep understanding of the relations occurring among materials and sustainable design, also providing practical skills and laboratory literacies to enable students to work with DIY, bio-fabricated and bioreceptive materials. The results of the course were analyzed through classroom observations, the analysis of student's projects, and a survey, confirming the efficacy of the proposed model in terms of final student's awareness and gained skills on the topics of sustainable design and the development of new circular, bio-fabricated and bioreceptive materials.

2.2 building new material design curricula for sustainable development

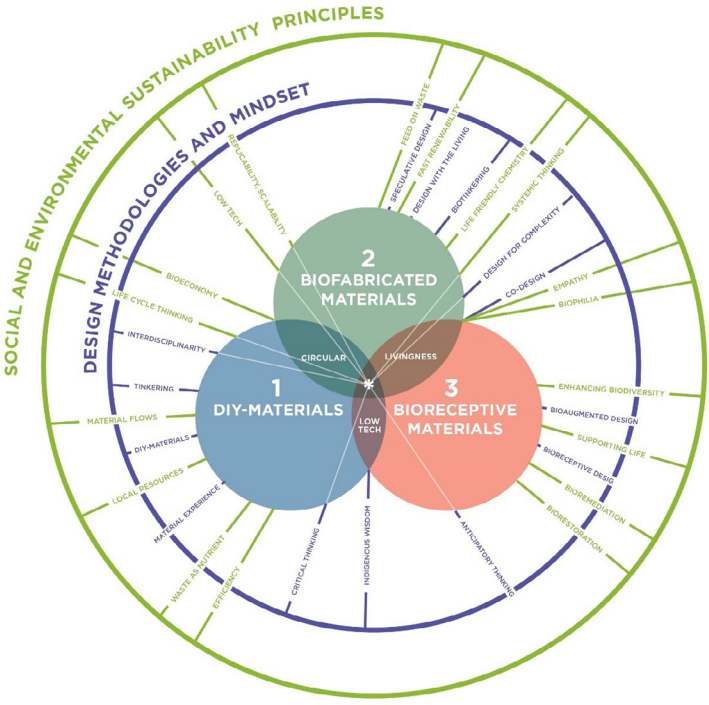
With a solid practice-based approach, aimed at guiding the students through three practical activities, the course focused on the possibility of creating sustainable materials in a crescendo of complexity: starting with the experimentation of DIY-Materials based on the analysis of local waste and resources, continuing with the experience of growing living materials such as bacterial cellulose and mycelium, and concluding a learning-by-doing path with bioreceptive materials, combining living and inert materials aimed at encouraging biodiversity, biophilia and bioremediation practices.

The course aims at improving students' understanding of the dynamic and innovative dimension of sustainability, by developing sustainability competencies in terms of materials evaluation, selection and design, which can meet the education aim of Sustainable Development Goal 4 (SDG 4); In particular, SDG Target 4.7 aim at Education for sustainable development and citizenship, pushing for knowledge, skills, values and attitudes, from local to global levels, to promote sustainable development. The proposed hands-on learning approach has among its outcomes the enhancement of some skills which have been highlighted as crucial competencies for sustainable development (Vallabh, 2018): systemic thinking, the ability to understand and design for complexity, anticipatory thinking (projection of solutions which might open new sustainable scenarios through a first speculative approach), critical thinking, co-design, empathy, interdisciplinary work.

The aim of the course was to build a syllabus to express the potentialities of material design in design education to foster sustainability awareness among young designers. The match between DIY-Materials, bio-fabricated materials and bioreceptive ones was built upon the

observation of shared design methodologies and sustainability principles by these approaches (Fig.1); the sequence of the three workshops was built on difficulty that occurs for the development of the material by the designer, which also reflects learning of the basics of life principles of sustainability, from reasoning about circular materials flows to the material and energy exchanges occurring in the relationships of an ecosystem with multiple agents.

Figure 1 Diagram showing how the themes of DIY-Materials, bio-fabricated materials and bioreceptive materials share similar design methodologies and interconnected sustainability principles.



Source: Authors

Description of the learning path through materials

Like many developing countries, Mexico recognizes its role as a producer of raw materials, playing a significant role in the globalized economic system. Even if the concept of a CE is relatively new, public policy and researchers seeking to implement a circular economy model are proliferating since both the literature and national statistics show significant potential in adopting a CE model (Munoz-Melendez et al., 2021). The general attention to new materials is not as strong here compared to other countries, unless triggered by large global industries[3]. However, biodesign is also feeding a small niche of interest in Mexico: this is relatively new but slowly growing in different sectors, finally developing projects local-related to waste streams and social needs. The Mexican scene can fit into the broader South American one, where a Biodesign Challenge Hub has recently been established, showing interest and active participation[4]. To make some Mexican examples, Taina Campos[5] is working on biomaterials employing corn leaves among other sources, and accompanying her work with a narrative that promotes the protection of native corn, food sovereignty, as well as supporting local women producers; Biology Studio by Edith Medina[6], is studying the intersection among biology, design and ancestral knowledge to create textiles using raw materials from bacteria, fungi, flowers and vegetables; Polybion[7] is a company creating high-performance biomaterials from locally produced fruit waste to craft

[3] An example of this phenomenon is the materials design residency promoted by Space 10, powered by Ikea, to explore the local biomaterials of Mexico. Although these design synergies can open global connections favorable to economic development (also in terms of circular and sustainable products), they don't necessarily contribute to local empowerment, but risk remaining an isolated phenomena. Retrieved 6 April 2022, from https://space10.com/residencies-tomorrows-materials/

[4] Retrieved 6 April 2022, from https://www.biodesignchallenge.org/pressblog/2021/april-15-latam-hub

[5] Retrieved 6 April 2022, from https://www.tainacampos.com/

[6] Retrieved 6 April 2022, from https://edithmedina.com/

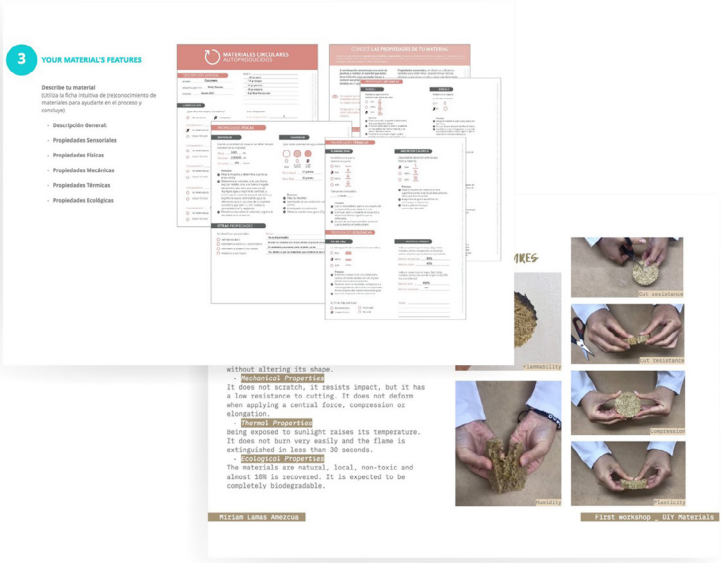
[7] Retrieved 6 April 2022, from https://www.polybion.bio/

a sustainable leather alternative. These examples show a turning point in the local design landscape, but it is important to highlight that in this area is more challenging to communicate the value of such projects, whose economic and environmental potential is still poorly understood by the design community and the industrial sector. Experiments in materials and biodesign are emerging trends in design. However, they are still little represented in the design of curricula in Mexico, as in the rest of the World when looking at the big picture, and not at some trendy niches in western countries. Some independent designers are working as pioneers in DIY or bio-fabricated circular materials. Still, the lack of knowledge in scientific disciplines could be a brake on experimentation in academic environments that are not yet highly interdisciplinary. For this reason, rethinking the designer's curriculum by including a theoretical and practical training on these emerging materialities can not only bring designers closer to the radical change that circular materials and biotechnologies can offer to the project, but it can also help them develop the skills needed to be professionals on a sustainable development trajectory. The course has been provided in Mexico as part of the ITESO elective International Summer course, and it lasted eight weeks. The aim of the course was to provide students with new ways of conceiving materials and their impacts. Taking circular design as a starting point, different methodologies for the development and application of new sustainable materials were discussed. The syllabus was nurtured by the authors' previous knowledge and teaching experience on sustainable design and materials. Having two different geographical perspectives, one European and the other Mexican, this difference enriched both the general method and the syllabus, creating a model that refers to the potential of the territory, but whose main educational structure can be applied anywhere in the World, precisely because it is based on the use of local resources and low tech processes. The topics covered by the course requirements are strongly interdisciplinary; in this sense, it was helpful to have a mixed class of designers and engineers who could cross-pollinate their previous knowledge for the design challenges proposed by

the course. The development of new materials, as well as the growth of living materials, requires skills that are missing in the traditional training paths of designers; for this reason, a series of cards and worksheets, used as a guide, analysis, and reflection tools, have been developed for each workshop, to help students in the research and design process, but above all developing systemic thinking. The first week of the course has been introductory, discussing the leading theories of sustainable design with a broad understanding of its evolution, from the principles of the early green design to the last guidelines of circular design, passing by the life cycle approach as a fundamental aspect for understanding the impacts of materials within the design project. From the second to the seventh week, three workshops were dedicated to developing students' practical knowledge on three different material scenarios: DIY-Materials, bio-fabricated materials, and bioreceptive once. The last and eighth week was dedicated to wrapping up and preparing the latest materials and prototypes for the last exhibition. Each workshop started with one day of theoretical content to introduce the different topics, including an introductory lecture from national and international guests afferent to the circular and new materials scene. The DIY Materials workshop started with a research and analysis of local wastes in view of the possibility of being revalued for the development of new circular material considering: the abundance of flows, current uses, type of production industry, and production scenarios, as well as the processing methods with research of case studies showing existing applications worldwide. After initial experimentation with the most well-known and widespread bioplastic recipes (which made the students familiar with the possibility of actually creating materials), students experimented with local waste, appreciating sugar cane, coconut and pineapple scraps. All these resources are abundantly present on the territory as part of the local supply chain. In addition, tools developed by the authors were used to perform the design process and the final material assessment through an intuitive approach. A procedural thinking material scheme has been proposed to support

students not to get lost in the many possibilities of experimenting with the material. Dedicated cards supported the intuitive analysis of the experiments carried out, to discover and appreciate material properties and applications. At the end of each laboratory, students were asked to identify the main characteristics of the new developed material through cards previously developed by the author for the ITESO Material Library (Fig.2), to recognize the properties of a material through the senses, referring to an intuitive approach, before using laboratory analyses. During the course, these cards were used on the most promising samples, guiding students through an intuitive knowledge of the material, so that they could change the design according to its current and desirable characteristics.

Figure 2. Intuitive materials analysis cards developed for Materioteca ITESO activities.



The second workshop was on bio-fabricated materials, here the students experimented the growth of two different growing materials (Camere & Karana, 2017), bacterial cellulose got from kombucha fermentation and mycelium. One of the most relevant aspects of this workshop has been the connection between local bio-designers and entrepreneurs. For this workshop the lectures and the starter kit with living materials were, in fact, provided by Radial biomaterials[8], a studio producing circular mycelium-based biomaterials from Agave residues, and Muutus biomaterials[9], a designer developing experimental materials and products based on bacterial cellulose from kombucha fermentation, especially for the textile sector of Aguascalientes, Mexico. The connection with designers operating on a market level, and showing the circular potential of bio-fabricated material from local waste streams, was a further aspect showing students the effectiveness of these materials for the regional bioeconomy. The worksheets supporting the second workshop focused on the organisms necessary for their growth, including a practical guide on how to work with living materials (basic wet lab skills). The third workshop introduced bioreceptive design, where the students were asked to think about inert/alive material assemblages to address local environmental issues related to polluted environments and biodiversity loss. The workshop started also in this case with research on the depleted or polluted zones of the territory; this helped make students aware of the area's environmental problems, looking for solutions in restoring the original environmental conditions through the project. Among the tools provided for the workshop, the bioreceptive material method (Pollini & Rognoli, 2021b) has been provided, supporting the work with worksheets dedicated to deepening the study of the organism and the environment to design the suitable artifact/material accordingly.

[8] Retrieved 6 April 2022, from https://radialbio.com/

[9] Retrieved 6 April 2022, from https://www.instagram.com/muutus.b/

Findings and results

To understand the adequacy of such a training proposal, correlating materials and sustainability and firmly rooted in knowledge through practice, the authors collected data during all the course through observation and field notes. Part of this analysis is related to a twenty-eight questions survey the students were asked to take at the end of the course to gather information about their overall experience regarding the presented topics and the three workshops' experiences. Ten students took part in the survey. The survey covered the students' background and their familiarity with the topics proposed within the course; in addition, for each workshop, the questions aimed to understand which aspects students perceived as more challenging, engaging, and valuable. Students were asked about the design methodologies and the practical knowledge gained through the workshops, and their perception of living materials in the design practice. Being the course an elective one, the students were asked about their motivations for taking the course; from the survey, the main trigger in subscribing appeared to be the will to know more about circular economy and sustainable materials alternatives. Students also referred to the practice of DIY and the emphasis on experimentation as key-point in deciding to take the course, while one student also valued the possibility of making it follow an entrepreneurial path. This answer confirms that sustainability, joined with a practice-based approach, is a powerful trigger for designers, who may even foresee taking an entrepreneurial way after a first educational stimulus. This path is, in fact, not new in material design and biodesign. Two significant examples are the dutch company StoneCycling[10], born as a startup based on Tom van Soest's thesis project on the upcycling of construction waste; in biodesign, the designer Maurizio Montalti, after a thesis on the use of mycelium as a "human-digestor" in a burial suite

[10] Retrieved 6 April 2022, from https://www.stonecycling.com/

with the project Continuous Bodies–Bodies of Change, continued his professional and working career designing with mycelium in various aspects (from speculative to workable), up to founding the first European company of products based on mycelium, Mogu[11].

The following three paragraphs will describe the student's feedback and the analyzed outcomes for each workshop.

4.1 Student's awareness and potentialities perceived in DIY-Materials

Regarding the first workshop, just over half of the participants were already familiar with the DIY-Materials concept. Among those who have declared themselves aware, just a few were already familiar with the process of bioplastic making. The answers were quite similar when the students were asked about the potential link between the practice of DIY-material and the concept of circular economy: all agreed on having realized the abundance of waste discovered by the first analysis of the territory. The students pointed out the potentiality observed while tinkering with those wastes, confirming the validity of the tinkering activity to envision new material possibilities. Asked about the major challenges in the DIY-materials process, students reported the challenge of not finding the right recipe and, therefore, feeling stuck in envisioning a application for the material. This initial frustration may derive from the feelings that designers experience in the path of trial and error typical of this approach (Rognoli et al., 2017), which does not aim at an immediate result, but it makes a value of the experimental and experiential path. However, most of the students successfully passed this first stage, reporting how the newfound ability to get samples of materials with an experimental practice was the most exciting aspect of the workshop. Many

[11] Retrieved 6 April 2022, from https://mogu.bio/

students have referred to the MDD method presented in the introductory theoretical lesson as a valid approach to envisioning applications.

Figure 3. Use of the provided tools and selected materials outcomes showing the DIY-Materials workshop process.

4.2 Student's awareness and potentialities perceived in bio-fabricated materials

Regarding the second workshop on bio-fabricated materials, just over half of the students didn't know about bio-fabrication. Among those familiar with the concept, algae, mycelium and bacteria were known for their material potentialities, reflecting actually the most experimented organisms in biodesign: it was interesting to notice, though, that the majority mentioned algae. In this experimental path, students reported that the principal challenges have been understanding the bio-fabricated material's real potentialities, the need to follow clean protocol conditions, and the time factor affecting the length of the experiments. Interestingly

enough, the primary concern turned out to be also one of the main valuable aspects of the workshop too; in fact, one third answered that understanding the bio-fabricated material's potentialities in design has been the real value of the practice-based activity, while the other participants referred to the possibility of creating something alive as the most triggering aspect. The students agreed that one of the most frustrating aspects was the uncertainty in the outcomes; many reported being afraid that something was wrong with their culture. Despite following the showed procedure, the growth variability was felt with a bit of anxiety that the organisms could not grow well. One student pointed out that "there is no specific pattern to follow, through experimentation and investigation is how you find out information, ", reflecting the uncertainty feeling also reported at the initial stage of the DIY-Material workshop. The class was composed of both design and engineering students: the authors noticed that while this explorative procedure might be enjoyable from a designer's point of view, from a more scientific and engineering one, uncertainty in the outcomes might be felt as frustrating. Once again, the survey reported the value of understanding the material properties through an experimental path: a student reported having particularly enjoyed "the liberty to be so creative and in charge of the process through all the course". A distinctive key concept here was the fascination of working with something alive and being able to follow its growth. The students positively evaluated the tools provided to guide them through the discovery of mycelium and bacterial cellulose as living materials (e.g., ID card, worksheet), declaring that they are likely to reuse them in the future.

The students were also asked about their perception of these alive materials for design: on the answers they split in half, the once relating to them as functional materials for design, but the other admitting to perceive them more than living organisms. The students agreed that the material feature that primarily identifies a material as bio-fabricated is a "non-homogeneous aesthetic of colors and shapes that changes over time".

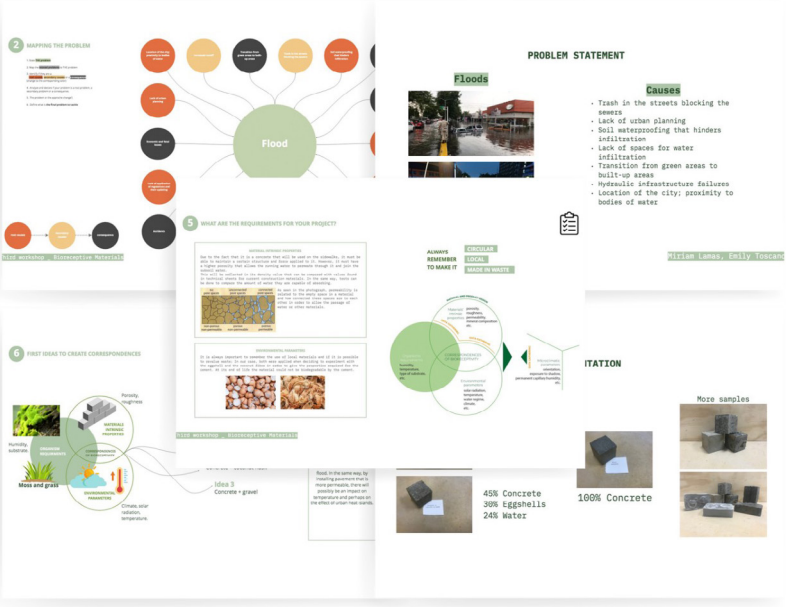
Figure 4. Use of the provided tools and selected materials outcomes showing the bio-fabricated materials workshop process.

4.3 Student's awareness and potentialities perceived in bioreceptive materials

Strangely enough (given the recent new definition proposed), two-thirds of the students stated to be familiar with the concept of bioreceptive design; however, the third workshop was probably the most challenging in design and planning. In fact, after two workshops in which the act of experimentation was guiding the design process, in the third workshop the students were asked to develop a project, choosing their basic materials and techniques to find a solution to a local environmental problem, taking into consideration the potential of bioreceptive materials for problems related to the loss of biodiversity and environmental pollution. The students saw in this "freedom", which required problem analysis and

design planning, too little time to conceive a good idea. Also, in this case, the challenge reported turned out to be the most exciting thing in finding a solution. The students said the concept and potentialities of bioreceptive design as more attractive. Still, they also declared that they enjoyed the entire design process, from the analysis of the problem to the designed material solution. Most of the students claimed the proposed method to be useful, but sometimes difficult to apply; some complained about a technicality such as the microclimatic parameters to be considered. This feedback will be helpful for the authors to simplify the method in future workshops with limited time for deep reflection.

Figure 5. Use of the provided tools and selected materials outcomes showing the bioreceptive materials workshop process.



4.4 Student's general opinion on the course

From more general questions on the entire course, all the students have shown sincere enthusiasm in working hands on with the material, confirming their will to pursue it in the future.

This feeling was also clear from observing students' attitudes; in fact, even if the course was in hybrid mode and the students could decide how much time to spend in the laboratory, they always used all the time available to them to experiment with the materials there.

To the critical question of how much this didactic approach has changed their perception of the role of materials in design for sustainability, the answers were all encouraging, reporting an increase in the environmental awareness of materials and their life cycle, and an interest in learning new techniques and material possibilities starting from circular models and the revaluation of territorial wastes. Students stated they realized the countless sustainable material alternatives that this approach can unveil and help develop: one of them stated "I think that before I saw the creation of a material as something unreachable that I could not do, but after this course I broke that barrier". The authors also recognized the advantage of having a mixed class of two disciplines (engineering and design) who could compare and collaborate, even compensating for the general attitude of their respective classical study; one student declared "Sometimes is difficult to see a more creative way of being an engineer. This course has allowed me to expand my horizons and realize that indeed I can be creative". As general advice for improving the course, the only sign was related to time. The students would have wanted more time, which is reasonable considering the time needed for experimentation, especially when living organisms are involved.

Conclusions

The outcomes of the course and the inquiry attitude of the students showed how materials direct experimentations can increase awareness of materials' life cycle, bringing the designer closer to local and wasted sources, to low-tech processes, and to the rediscovery of ancient practices and designerly way of knowing. The recent democratization of scientific knowledge opens up the possibility for design to hybridize with other scientific disciplines and to experiment with living organisms, creating bio-fabricated materials generated through biological growth processes, or bioreceptive materials, able to support living forms for healthier and synergetic environments. To be grasped by designers and engineers, these emerging new materialities need to be considered in their classical training, to enhance a deep knowledge of the dynamics that relates materials to the impacts of design project, but also to introduce students to the basic techniques for the experiential knowledge of these new emerging materials. One of the key aspects of the course has been the connection with local resources and professionals in the field. The students started with a focus on the organic waste of the territory, realizing the linear management of valuable sources deriving mainly from the food supply chain, and being able to envision them in a circular economy perspective through design practice. The materials' samples showed them, experientially and experimentally, how a circular model could work and what potential (still unexpressed) their territory could exploit. In biodesign and bio-fabricated materials, knowing the local realities, allowed students to approach the topic in a rooted way with their territory, opening the possibility for them to refer or even join the local and regional biodesign scene that already actively contribute to innovation in biotechnologies. The last workshop allowed the students to approach local environmental problems. This analysis merged the fundamental aspects of the entire path, challenging the students to combine the World of inert materials with living ones for multi-species

design projects where the living part could also contribute to the protection and healthiness of local ecosystems. The field observations and the results of the survey proved the effectiveness of this pedagogical approach in increasing students' environmental awareness, passing through an experiential study that helped them to focus on the dynamics that bind the material to the project, providing methods and useful tools to develop skills such as systemic and critical thinking, empathy and interdisciplinarity, that are fundamental to train capable professionals to lead sustainable development. Following the student's suggestions, further editions of the course should dedicate more time to the second and third workshops, while smoothing the learning path in bioreceptive design with additional supporting tools or avoiding technicalities is unnecessary for a first approach to this more complex theme. As a last consideration, the educational approach presented here is based on interdisciplinarity; therefore, it can find usefulness in the training paths of designers and engineers, who in equal measure can contribute to the development of the discipline of material design for the ecological transition.

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Challenges to wearable design education from a sustainability perspective

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Abstract

Current clothing purchasing behavior is not sustainable. Consumers are buying more clothes and wearing them for less time, leading to higher levels of carbon dioxide in the production, use and disposal of clothing. As sustainability becomes the norm in the fashion industry, consumers who play an important role in the life cycle of clothing need to understand the environmental impact of their clothing choices. Researchers call for more research on practices and methods to educate consumers and therefore apparel designers about the environmental impact of textile and garment consumption to determine and define design methodologies that lessen that impact (Abner et al., 2019; Armstrong et al., 2016; Connell & Kozar, 2012; Ha-Brookshire & Norum, 2011; Kang & Kim, 2013; McNeill & Moore, 2015).

Awareness of the environmental issues associated with increased apparel consumption has influenced how the textile and apparel industry responds. As fashion sustainability issues have become more public and politicized, companies that produce and sell apparel and textiles have developed standards to determine the preferred attributes of sustainable products (REI Staff, 2018).

Consumer use of so-called wearables - portable or wearable technology - makes up 10% of part of the apparel product lifecycle, growing at 4% per year globally. The use, care and disposal of this type of wearable has a significant impact on the environment through the use of energy, water and textile waste (Ellen MacArthur Foundation, 2017). Part of the responsibility lies in the hands of consumers and another part in the hands of designers who generate wearables to solve high impact issues but need to include sustainability practices to ensure the sustainability of this new category of products.

This chapter aims to show a synthesis of the characteristics that must be met in the design of wearable products, and the drivers that are considered in the purchase of garments developed under sustainability criteria, in order to understand the fit of the two models.

Keywords: Apparel design, wearables, technology, consumer.

The design of wearables

The term wearables refer to electronic and computer technology that is incorporated into wearable accessories or clothing and generates an organic interaction with the body. These devices can perform many of the same tasks and functions as smartphones, laptops, and tablets. However, sometimes, these devices perform tasks

more conveniently and efficiently than portable and wearable devices. They also are more complex in terms of sensory feedback and actuation capabilities than traditional technology equipment. The goal of wearable technology is to provide reliable, consistent, convenient, continuous and hands-free digital services for their operation, which makes these features fundamental requirements for the design of such wearables, and given the scrap nature of some parts used for batteries, microcontrollers, sensors and other wearable components, it is important to incorporate sustainability features to ensure the low impact of such products.

Wearable devices often provide a communication and feedback to allow users to view/access information in real time. A user-friendly interface is also an essential feature of these devices, as well as an ergonomic design, understanding from this point of view the inclusion variables that generate high impact social sustainability.

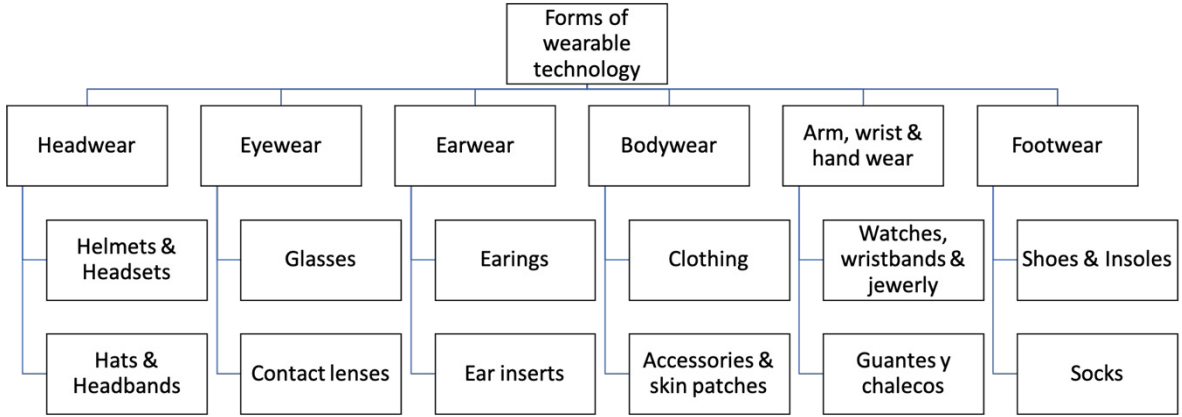
Figure 1 shows the most important representations of wearables usage occasions in apparel design.

While typical wearables refer to elements that can be attached to the surface of the body or clothing, there are also more invasive forms, such as implantable electronics and sensors. These types of parts have not been considered in the analysis given their complexity of bio-compatibility and their bioengineered design nature.

Characteristics of wearables

Wearables must be versatile garments with application potential for recording variables associated with medicine, health, sports, aging, disability, education, transportation, business and entertainment. In these fields, the principal aim of wearables is to seamlessly integrate functional and wearable electronics into the daily lives of users. Before

Figure 1. Representations of wearables



the consumer market, wearables were mainly used in military and high-precision healthcare technology. Portable devices share many aspects of observation, connectivity, automation and intelligence with IoT devices.

In the design of this type of wearables the morphological factor is an aspect associated with the hardware design in the electronic packaging that defines the size, shape, weight of the part, almost always determined by assembly of the controller, battery and sensors of the system. While wearables, by design, require a smaller form factor, this relationship is actually determined by the biomechanics of their use. Smaller form factors can provide lower material usage, easier handling and simpler logistics; however, they often result in higher design and manufacturing costs, as well as signal integrity issues and maintenance limitations.

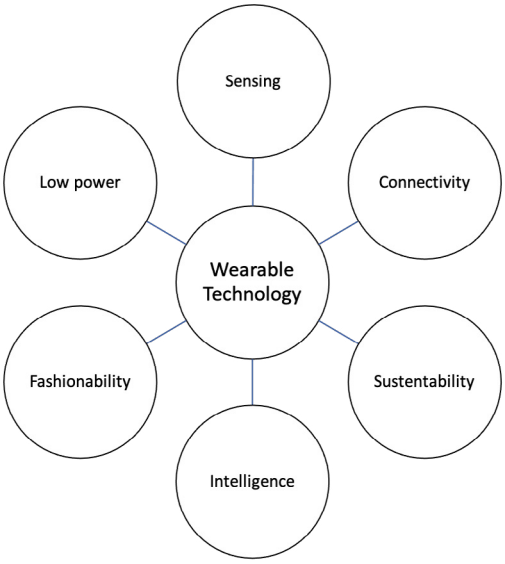
The durability factor is fundamental as it determines the cost of technology involved with the perceived obsolescence of the piece, giving rise to one of the important items in the design of wearables, associated with the exchange of parts that allow to change the aesthetics of the piece from the technological core that processes the information, in the design it is important to consider the final disposition of this core, given the materials that comprise it, from lithium batteries, to biopolymers of high mechanical performance.

Ergonomics factors are also important considering the miniaturization process that wearables must develop in their design process. Figure 2 shows the most important features to consider in the design of wearables.

Challenges of wearable design

While wearables continue to transform our lives in the 21st century, significant challenges are emerging from their design that, if not considered in their design education, can prevent them from realizing

Figure 2. Characteristics of wearables



their full potential. These are the fundamental challenges that require full attention:

Security education

Security is one cornerstone of the Internet and the most important challenge facing wearables. Hacking of fitness trackers, security cameras, baby monitors and other abuses has drawn the attention of many of the world's leading tech companies and government agencies. While security considerations are not new to the world of information technology, the characteristics of many wearable design implementations present unprecedented security challenges. As the design of these types of products become ubiquitous and integrated into our daily lives, users must keep these devices and associated data safe from vulnerabilities such as cyber-attacks.

Concerns about the design of wearables at this level will no longer be limited to protecting our data and intangible assets; this challenge is magnified by other considerations, such as the mass production of identical devices, the capabilities of identical devices to determine the behavior of their users, the ability of certain devices to automatically pair with other devices and the potential use of those devices in unsecured environments.

Privacy education

While many emerging wearables are generating innovative applications and uses, as well as promising and attractive benefits, they also raise unexplored privacy concerns, most of these devices need to interact and share data with access points (i.e., smart watches to smart phones, medical monitoring devices to home servers, light bulb home assistants to home controllers) and other sensors and peripherals will certainly generate a new class of privacy and security de-risking.

Some of these devices implement, by design, multiple sensors to collect a wide range of biological, environmental, behavioral and social information from and for their users. Obviously, the more they become part of our daily lives, the more sensitive information they store, process and transmit, which also raises privacy concerns. Built-in surveillance or voice recognition capabilities constantly eavesdrop on conversations or video recording activity and selectively transmit this potentially sensitive data to cloud services for processing, sometimes involving third parties. Processing and interacting with this information demonstrate the legal and regulatory challenges facing privacy and data protection laws.

The challenge for educating design models will increase when these devices are integrated with facial recognition programs that allow users

to see people's names, personal information and even access their social media accounts in plain sight.

Education of the norm

The lack of standards and documentation of best practices is a major limitation to the potential of wearables. Without standards to guide designers, these often-disruptive products can lead to interoperability issues and, if not designed and configured correctly, can have negative consequences, affecting, for example, the network to which they are connected and possibly the Internet. Unfortunately, this is mainly due to cost constraints and the pressing need to get the product to market before the competition, and with versatility governed by today's fast fashion.

Legal issues related to wearables may include conflicts between government oversight and civil rights. Considering that the technology is developing much faster than the associated regulatory and policy environment, which can make products and their interactions with users conflicting.

In addition, the cloud or even the Internet itself is not limited by a specific geographic location and the sheer volume of wearables comes from many different sources, including international partners and suppliers, making quality control or standardized testing impossible for local regulators.

Sustainability education from "Energy issues".

Increasing data rates and the number of Internet-enabled services, along with the exponential growth in wearables, are driving networks to

consume more power. In addition, the drive for smaller size and lower power consumption is creating more signal integrity and power issues in wearables, rendering their performance faulty in the short term and leaving a scrap and buyback trace much higher than even the current market dynamics.

Common problems include distortion, excessive losses, impedance mismatches, and generator noise. If these issues are not addressed, these devices could be adversely affected and create consumption dynamics beyond the capabilities of current sustainable standards.

Education in “connectivity

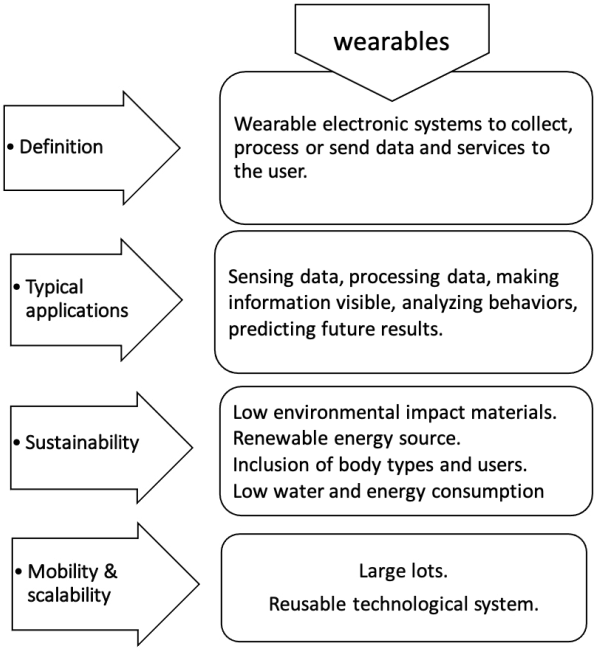
It is only a matter of time before users experience major bottlenecks in connectivity, competency and performance of their wearables with the current rate of growth in wearable design and development. Today, a large percentage of connected devices rely on centralized client/server platforms to authenticate, authorize and connect to other nodes in a network. This model is sufficient for now, but as billions of devices are added to the network, these platforms will become the bottleneck. These systems will require upgraded cloud servers to handle such a high volume of information traffic.

Figure 3 shows the dimensions of wearables and their impacts on sustainability.

Education of wearable design with sustainability.

The basic concept of sustainability applied to wearable design is given by “meeting current needs without compromising needs in the future”

Figure 3. Dimensions of sustainable wearables



(Johnson et al., 2016). McKeown and other researchers identified three principles of sustainability, where these three principles are necessary to address education for sustainable development, the first principle is economically based, the second is environmentally based, and the third is socially based.

Protecting the environment while adapting to economic development is an important ecological trend currently affecting the training of apparel designers, especially those focusing on the area of wearables with a strong emphasis on consumer trends (Harden et al., 2014).

With the rise of the global fast fashion trend, wearable consumption continues to increase, creating dangerously high levels of carbon dioxide emissions and other toxins in the global ecosystem and this dynamic is

being a consumption odel that determines the behavior of wearables in the marketplace. Both industry and consumers must act to reduce carbon dioxide (CO2) emissions and textile waste (Ellen MacArthur Foundation, 2017). The industry is increasingly aware of sustainability issues and is implementing practices to improve sustainability. As awareness increases, many companies are working to improve and innovate many aspects of their industries to meet and comply with sustainability standards (Cattermole, 2018; Fashion United, 2020; REI Staff, 2018).

Consumers have been slower to change behaviors associated with apparel consumption. Although customers support companies changing be more sustainable, 71% are not willing to pay more for sustainable clothing (NOSTO, 2019).

Sustainable wearables type products have specific characteristics that are determined by: sustainable raw materials, reduced use of fossil fuel energy, reduced use of toxic chemicals, and reduced water use. The supply of sustainable clothing is increasing and the option of wearables in the same category is an important alternative. It is important to embrace the steps that companies in the apparel industry are taking to improve the environmental impact of apparel production. In examining the associated risk factors that significantly influence consumers purchasing sustainable garments, the same categories of perceived risk were used. Kang and Kim's (2013) research assessed risk perceptions of such sustainable garments among young consumers. The risks examined are: financial, performance, psychological and social risks. The hallmark of financial risk is high-priced clothing that also includes low-cost use and care (Kang and Kim, 2013). Psychological risks are closely related to performance risks; however, these risks are associated with negative perceptions of self-image (Kang & Kim, 2013). Friends and family consider these fashionable or popular garments to define social risk (Kang & Kim, 2013).

For the developed research we adopted the measurement of the same variables in current market wearable systems (smart watches, monitoring bands, etc) with emphasis on their sustainable design and found that financial risk is the most important barrier to purchase this type of product, that psychological risk directly determines attitudes towards wearable use, that social risk has little impact on wearable purchases because of the observation that it is difficult to determine if it is a sustainable product without a label or logo and performance risk was not significant.

These perceived risks fit easily with the factors of Ajzen's (1991) theory of planned behavior; the theoretical framework used to guide this research. Although economic and environmental sustainability factors are two of the three principles of sustainability, social aspects must also be considered.

Sustainable and consumer-focused wearables

Fast fashion trends coupled with an increase in textile waste have reinforced the need for sustainable-based education for new product categories. Teaching about sustainability and using teaching strategies and methods that encourage sustainable behavior is one way to combat overconsumption (Harden et al., 2014).

Certain areas of wearable design are better for teaching sustainability issues. For example, Ulasewicz and Vouchilas (2008) studied courses at the University of California and found that courses in wearable design with technology and interior design vary widely in the application of sustainability topics. Interior design includes sustainability in most aspects of the curriculum, while apparel design with technology courses address sustainability in only one of their courses and nurture the curriculum with the implications of technology. Courses with a strong

sustainability background influence students' knowledge, causing them to consider sustainability options more often, from a technological standpoint, which leaves sustainability not as a design option but as a prerequisite of the system to be designed. Before teachers can develop curricula and choose teaching methods to disseminate information on how to better manage the earth, wearable design professionals need a better understanding of the factors that guide consumers in their product choices to turn sustainability into a product's competitive advantage.

Variables influencing the purchase of sustainable wearables:

Knowledge about impacts.

Increasing students' knowledge of social and environmental issues related to wearables is one way to influence sustainable consumer behavior (Connell and Kozar, 2012). The concept identified by Thompson et al. (2012) posits that a focus on environmental issues such as exploring carbon footprints of materials and processes, solid waste, and water should be used. The U.S. Environmental Protection Agency annually reports facts and figures on waste materials, waste and recycling of textiles on its website, being a significant source of information to monitor the performance of wearable-type products that are manufactured and discarded.

In 2010, about 13.2 million tons of textile waste and technology waste were generated, 8.9 million tons were landfilled, and about 2 million tons were recycled. Non-durable goods waste (products with a useful life of three years or less) has decreased since UNESCO established sustainability standards in 2005, but textile and technology waste has increased. The facts and figures further illustrate the enormous need to

address the environmental impact of clothing consumption habits and the birth of wearable consumption.

Sharing knowledge about textile waste has the potential to reduce waste generation, formal methods of sustainability education significantly influence behavior change more than informal education methods.

Environmental concern

Yeung (2004) defines environmental concern as "an emotional attribute that expresses an individual's concern, empathy, likes and dislikes for the environment." Environmental concerns are easily translated into action because of emotional connections. Researchers Joshi and Rahman found a very large connection when examining consumer awareness of environmental issues related to apparel production and consumption. Lundblad and Davies (2016) found significant patterns of motivation to address environmental problems among environmentally concerned consumers, including responsibility and a desire to protect the planet. Those who feel responsible for addressing environmental problems do so by taking responsibility for how they consume and hope to educate others to develop similar habits. These habits include buying products made from natural materials, learning about eco-friendly production techniques and buying recycled clothing, where repaired wearables are an option. Post-purchase habits or activities that are positively associated with environmental concerns involve greater use of apparel products, including wearables (care, repair and recycling).

Attitude.

The individual meaning associated with attitude comes from the "like or dislike" paradox (Ajzen & Fishbein, 1980). Ajzen and Fishbein recommend

using a bipolar rating scale when assessing attitudes. The more positive the attitude toward the expected behavior, the more likely the individual is to perform it.

When assessing attitudes towards sustainable clothing and sustainable wearables, the determinants of attitudes should be identified. There are several research studies that cite lack of consumer knowledge, product availability, financial resources, retail environment and social norms as reasons for people's poor attitudes toward these types of products. Color and style are powerful influencers of choice. These performance factors outweigh the ethical factors associated with the sustainability of apparel and wearables.

An individual's perception of sustainable product consumption depends on the "perceived relevance and value of products, perceived effectiveness for impact on the environment or society, and perceived losses and gains", these perceptions influence people's attitudes towards consuming these types of products.

Subjective normativity

Subjective normativity refers to an individual's perception of his or her commercial validator's willingness to buy or not to buy sustainable products. According to Ajzen and Fishbein (1980), "The more a person thinks that other people who are important to him believe he should take a certain action, the more he intends to do so." In assessing subjective norms, a measure to align intentions and actions is recommended.

There is a negative relationship between consumer knowledge and subjective norms about sustainable wearables, the greater the knowledge of this type of product and its generation, the more it is negatively associated with subjective norms, this finding suggests

that informed consumers are less influenced by subjective norms that do not support this type of purchase. The worst enemy for the sale of wearable-type products based on sustainable design models is consumer misinformation.

In addition, an emphasis on positive and sustainable "lifestyles, values and self-image" will increase an individual's perceived self-importance and consumers who associate fashion with identity, especially younger consumers, are the least concerned about the environmental and ethical considerations associated with these types of products. Thus, efforts to promote subjective norms and attitudes toward sustainable clothing consumption may have the greatest impact on changing perceived behavioral control and purchase intentions.

Conclusion

Apparel design education for wearables emphasis should have a fundamental category as a pillar of their training in sustainability seen as a prerequisite for product performance in the marketplace, but also as an argument in their marketing. Consumers are currently determined by consumption variables that try to shape the conscious purchase of the sustainable product; therefore, the development of wearable products must generate communication dynamics that enhance this change because they handle the textile impact associated with their product and the technological impact that is another source of detriment to the planet.

In short, wearables are members of the new group of environmental impact of the recent industrial revolution. As we move forward and develop by turning data into information, knowledge and wisdom, these technologies have the potential to transform the world as we know it today in new and exciting ways, but leave a very negative footprint if they are not designed from sustainability standards and sustainability is not

included as a fundamental platform of design education for this category of products.

Discussions on how to educate sustainability of technology-based apparel design show a lack of evidence on what teaching practices and learning activities develop better competencies in students and generate changes in technology-enabled apparel purchasing behavior. The research developed has merged the wearable design model with sustainability and reading from the planned behavior method to understand end-consumer dispositions.

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Crafts, art and product design from agro-waste of Nopal cultivated in Sonsón, Antioquia[1]

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[1] Research Project: Desarrollo de nuevos productos para la valorización de residuos derivados del cultivo de nopal en Sonsón, Antioquia. Rdo. PCI21204

Abstract

This chapter shows, in a documentary way, the role of nopal in the social and cultural development of the municipality of Sonsón, Antioquia, highlighting its history and its impact on hundreds of families of this region. The nopal has historically been cultivated in Sonsón to harvest one of its flagship products, the fig; an exotic fruit cultivated primarily for export, and much less for local consumption. However, it is known that all parts of the plant are usable, including the waste associated with its pruning. In Colombia, the complete exploration of the entire plant has been timidly explored, so new potential uses beyond harvesting the fruit are unknown.

This document exposes the potential of nopal waste in the development of craft, art, and product design pieces using eco-design strategies based on circular economy trends. Hence, a look to an integral use of the plant allows the tradition of the so-called "fig trees" to endure over time, avoiding the threats associated with new agricultural products that promise the farmers "greater benefits" for the livelihood of their families and the development of the region.

This look, in addition, will contribute to responding to some of the Sustainable Development Goals - SDGs through interdisciplinary work between academy, public and private sectors, and citizen interest, promoting the encounter of scientific and artistic communities around the nopal, through the development of a museum exhibition in Medellin's Botanical Garden, which allows to exalt the nopal as an alternative for the sustainability of families in the municipality of Sonsón.

Keywords: Nopal, agro-waste, craft, product design, sustainability.

Sonsón territory

Sonsón was founded on August 4, 1800 during the Spanish Colonization of Antioquia, in western Colombia. For about a hundred years, Sonsón was the engine of the colonization of the west of the country (Parra Bedoya & Parra Arcila, 2009; Toro Gutiérrez, 2015). The history of this municipality has also been marked by a period of violence. In 1970, the settlement of armed groups in different villages and districts gave rise a period known as low intensity conflict that lasted until 1995 (Infografico línea de tiempo Sonsón, 2017; Montoya Ramírez et al., 2019). The armed conflict in Colombia worsened, generating an alarming humanitarian crisis that left several municipalities in eastern Antioquia: San Carlos, San Rafael, Granada, Cocorná, San Francisco, San Luis, Argelia, La Unión, Nariño and Sonsón; that started during the presidential period of Belisario Betancur (Montoya Ramírez et al., 2019).

Sonsón is the largest municipality in eastern Antioquia, with an area of 1323 km^2. Its territory occupies a vast geographical area that goes from the Caucana slope to the Magdalena River slope (Montes Henao et al., 2020). It has 8 corregimientos or small districts, 108 villages, and 36.000 inhabitants, Figure 1 (Alzate, 2017; Montes Henao et al., 2020).

Its urban area is on the western side of the Cordillera Central at 2475 masl, and covers 1.6 km^2 of the total extension of the municipality, Figure 2 (García Isaza, 2009; Montes Henao et al., 2020; Montoya Ramírez et al., 2019; A. Osorio, comunicación personal, 18 de diciembre de 2020).

Economic activities

Near 83% of Sonsón's economy is driven by the agricultural industry. The remaining 17% is moved by culture, education, infrastructure, and environmental sectors. A few years ago, Sonsón was known for cereals

Figure 1. Map of the municipality of Sonsón (Henao García, 2012).

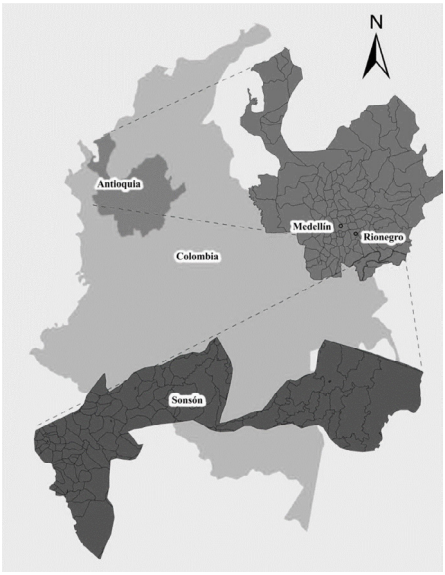


Figure 2. Location of the urban area of Sonsón (letf) and from Quintero brothers house, the most beautiful balcony in Antioquia, in the major park (right).

production such as corn, orzo, wheat, barley, among others. However, when the armed conflict ceased (Montoya Ramírez et al., 2019), much of their agricultural activities were industrialized in order to grown exportations of other products such as gulupa, passion fruit, and figs

(a few tons to Ecuador and Central America). Recently, products such as avocado has displaced many of the traditional products of the region because of the investment of large foreign companies (A. Osorio, comunicación personal, 18 de diciembre de 2020).

Nowadays, Sonsón has 38 productive items. The fig, together with the coffee, represent the emblematic products of the municipality. Those with the greatest impact, based on the number of families that benefit from them, are fig, coffee, avocado, dairy and dual-purpose cattle.

Additional, the cultural landscape of fig trees is unique Figure 3, which is an advantage that should be highlighted as a difference factor from other municipalities of Antioquia, and as an opportunity to explore and develop the culture of the fig (A. Osorio, comunicación personal, 18 de diciembre de 2020; Parra Bedoya & Parra Arcila, 2009).

Figure 3. Fig crop in Alto de Sabana village (Left/Own source); and Arma river Canyon took from Los Medios village (Montes Henao et al., 2020).

The nopal in Sonsón

The nopal is an endemic plant of the American continent. Belongs to the cacti group to Opuntia and Nopalea genera. It grows in territories from Canada to Argentina. However, Mexico has the greatest diversity of species. This plant is intimately linked to the history of Mexico, which, even on its shield, has a representation of an eagle stand on a nopal plant.

Since pre-Hispanic times, it has been used in different fields such as food, medicine, construction, and arts and crafts (Contreras-Padilla et al., 2012; Finck-Pastrana, 2014; Guzmán Lechuga, 2016; Inglese et al., 2018; Marin-Bustamante et al., 2017; Murillo-Amador et al., 1998; Torres-Ponce et al., 2015). In Colombia, nopal cultivation had not been recognized until a few years ago, and because of this, it is not planted or processed efficiently. It has great economic projection that may contribute to country's economy. Additionaly, it has become a solution to overcome the harsh drought conditions in some regions, as of Mesa de los Santos (Santander) (Baena, 2014).

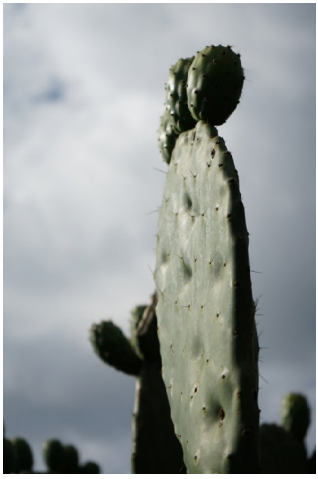
It is common to find that the nopal spreads easily thanks to its root system that allows it to grow in its underground and aerial stems, as well as in its leaves (Rivera, 2016). It is known that it bears fruit throughout its life. In Sonsón, nopal crops are mainly focused for harvesting and marketing its fruit, the fig, which gives its name to the well-known "higeras" (fig-trees). This economic activity represents the livelihood of near 500 families, where about 93 hectares (ha) planted represent a production of 25 tons per hectare each year (data provided by "La Higuera Asociación") (Rivera, 2016).

The role of fig in Sonsón

Sonsón has the privilege of being the only municipality in the department of Antioquia that harvests the fig, which makes it an exotic fruit and one of its flagship products, Figure 4. In Colombia, there are only two municipalities that grow export-quality figs: Iza, in Boyacá, and Sonsón. However, it is known that there are crops in other departments such as La Mesa de los Santos, in Santander.

Historically, fig trees have been the economic support for hundreds of families (A. Osorio, comunicación personal, 18 de diciembre de 2020). Despite of this, its production still has several problems to solve. One of them is related to transportation of the fruit to the distribution centers. Currently, over 40 tons of figs are lost per month because of poor accessibility to sidewalks and the difficulty of keeping the fruit in good conditions.

Figure 4. Nopal leaves with figs grown in Altos de Sabana village (own source).



Farmers also claims that nopal “does not represent a substantial income”, and it has been displaced by other agricultural products such as avocado (A. A. Escobar, comunicación personal, 17 de octubre de 2021; B. Jaramillo, comunicación personal, agosto de 2021; U. Ospina, comunicación personal, agosto de 2021; J. Panesso, comunicación personal, 17 de octubre de 2021), which has become a latent threat in the nopal’s disappearance. This issue has led the authorities to consider the declaration of the fig as intangible heritage associated with agriculture.

Arrival of the nopal to Sonsón from popular knowledge

One thing to highlight is that the history of the nopal in Sonsón is still to be built, and it is, according to José Fernando Botero Grisales, Operative Technician in Culture and Heritage of the Municipality of Sonsón, “a historical debt that we still have”. There have been identified fig trees of up to 80 years old, which represents an opportunity to recover the identity of Sonsón based on the historical value of the nopal.

Some stories collected from interviews made to farmers in Alto de Sabanas, allowed an approach to nopal arrival to Sonsón from the popular knowledge. Ubelio Ospina, a renowned fig grower, tells that fig arrived to Sonsón 120 years ago. According to Ubelio, his grandparents brought the first plants to El Roblal Arriba, where can still be found 5 of these ancient trees (U. Ospina, comunicación personal, agosto de 2021).

Another story told by Berta Jaramillo, says that the fig supposedly comes from a small river called Maitamá, where was the settlement of the cacique that bears the same name. This version coincides with that of Jaime Panesso, who also reported that it is a story that he was told since he was a child (B. Jaramillo, comunicación personal, agosto de 2021; J.

Panesso, comunicación personal, 17 de octubre de 2021). Jaime Panesso also says that it is believed that the fig was brought by birds that flew from Mexico, since the indigeneous could not walk such a long distances (J. Panesso, comunicación personal, 17 de octubre de 2021).

Weather and ease of growing in the unique conditions of Sonsón

This plant grows in Sonsón because of the microclimate that forms in the corridor of Sonsón´s paramo because the humid warm winds come together from the Magdalena slope, and cross with the dry warm winds of the Cauca River. These two streams intersect at the crest of the paramo and spill the microclimate (J. F. Botero Grisales, comunicación personal, 17 de octubre de 2021; A. A. Escobar, comunicación personal, 17 de octubre de 2021; B. Jaramillo, comunicación personal, agosto de 2021; U. Ospina, comunicación personal, agosto de 2021; J. Panesso, comunicación personal, 17 de octubre de 2021). These conditions favored the grown of high-quality figs. Ubelio Ospina says “Even though in La Mesa de los Santos and in Boyacá the plants are smaller, the fig pulp quality is better in Sonsón” (U. Ospina, comunicación personal, agosto de 2021).

During a visit of nopal experts from Mexico, they told Sonsón’s farmers that it was strange to see nopal in these green lands without deserts, and with those dimensions. In Mexico, they have plants of maximum 1.8 m tall which are easy to handle. It is because they only sow one leaf per plant, while in Sonsón they plant 3 or 4 leaves, which explains why it sprouts better and the enormous size of the plants Figure 5. In Sonsón, farmers figured out how to harvest the fig. Ubelio Ospina says “we didn’t learn it from anyone. We use a punch or needle, and a blade”.

Figure 5. Nopal plantation in El Brasil village (own source).

Collectors work and insights

The fig has a special value because it is the only plant that produces all year round, if it is well managed (A. A. Escobar, comunicación personal, 17 de octubre de 2021; U. Ospina, comunicación personal, agosto de 2021). “Right now, the avocado fever is leading everyone to plant it because it is a good option. It is easier to handle, and is better known by consumers, while fig is not known by almost anyone in Colombia” (U. Ospina, comunicación personal, agosto de 2021). But it is known that the fig is the only fruit that needs minimal chemical products, mineral fertilizers work very well, and organic fertilizers are used. It needs an important pruning management and small amounts of water. The fig, compare to many other fruits, is the least contaminating.

here are two big harvest times a year, from November to January, and from June to August, which is the best time (J. Panesso, comunicación

personal, 17 de octubre de 2021). A nopal produces 2 kilos of fig per week (12 to 16 figs), and it is sold at $3,500 COP per kilo. In Sonsón, the maximum production is 31 tons per week. “People realized that it is easier to handle avocado than fig due to the spines, so fig’s production has dropped” (U. Ospina, comunicación personal, agosto de 2021).

Dual crop: difficulty of its harvest and collection

The drawback of the fig are the spines (also known as pelusa or fluff) or the guate as the Mexicans call it (U. Ospina, comunicación personal, agosto de 2021). To be able hold it by hand, it is necessary to wash it with gloves, a tow, or a spoon to remove all the fluff, and hence it can be able to be consumed (J. Panesso, comunicación personal, 17 de octubre de 2021). In Colombia the culture of consuming fig is very poor (U. Ospina, comunicación personal, agosto de 2021), and sometimes they do not even buy it.

Despite of that, and because of the mentioned benefits of fig crops, they provide the minimum economic sustenance for the families (Marzola, 2021).

Products got from nopal in Sonsón

The Food and Agriculture Organization of the United Nations (FAO), described the nopal in 2013 as the food of the future, because it offers important nutritional properties in times of drought, becoming sustainable in the face of global climate change (Inglese et al., 2018). In countries like Mexico, the nopal is recognized for its applications in the food industry, with the young leaves being the primary product for consumption. However, other types of use have been registered thanks to

its high agrotechnological potential, being the base element for obtaining products that derive from industries already known as food (leaves and fruits can be consumed as vegetables and fresh fruit), medicine (for obesity and diabetes treatment) and cosmetics (soaps) (Marzola, 2021). In addition, new applications aim to respond to needs in fields such as materials science, design and art that allow to broaden the spectrum of its potential uses, Figure 6 (González & Ramírez, 2007; Marin-Bustamante et al., 2017; Torres-Ponce et al., 2015).

In Colombia has not begun with the awareness about the environmental benefits that the nopal planting brings, nor about the potential developments that derive from the integral use of the plant, and not only the leaves, fruits and flowers of the nopal are usable. Recently in Sonsón, some work has begun with fig by-products. The Municipal Association of Women Ana María Martínez de Nisser, produces nopalitos, marmalades, wines, flavored waters, among others. These initiatives make possible to promote the construction of the municipality's identity.

Figure 6. Teamwork interacting with nopal plantations in Altos de Sabana village (own source).

Opportunities for recent developments derived from nopal

The waste associated with pruning processes opens a window of possibilities to be used in multiple applications. Currently, the pruning waste is left on the ground to become the medium that gives growth to new plants, or to compost the existing plants.

Approximately 14 years ago, Ana María Orozco, an artisan and habitant of Sonsón, Figure 7, has worked empirically on the development of new alternative uses for the waste generated during the pruning of fig trees, to transform it into usable raw material to get different artisanal products («Creatividad e ingenio en Sonsón. Diseños en penca de nopal», 2016; Parra Bedoya & Parra Arcila, 2009). She says:

> "I've always liked art, so I started looking at those residues, and I started collecting material. Since that I felt in love with the work. The material

Figure 7. Ana María Orozco holding wastes and tender leaves of nopal, product of the pruning of a fig tree in Alto de Sabanas village (own source).

seemed to me to have a very nice texture, I worked on it in small things and thus I created" (Marzola, 2021)

With the development of lamps, caskets and vases, she has achieved recognition for her work at local and departmental levels. She has become as a benchmark for visualizing development options through the efficient use of the entire plant.

Agro-industrial waste applications in crafts, art and product design

Including crafts in the production methods of the regions could bring benefits at the local industry, and even though it apparently detaches from the globalized model that standardizes cultures and unifies society, production at the local level reactivates the microeconomy and promotes the circular economy. To generate income for the countryside, and even for demobilized sectors and victims of violence, if it is well organized, it can contribute to economic and social development. It may contribute to solve the problems of the Colombian countryside and the areas affected by the monetary and multidimensional poverty (Muñoz de Gaviria, 2013).

Craft development has traditionally been done from the countryside, in indigenous areas or in some areas of large cities. The techniques used for its development are ancestral or come from ethnic groups, cultures, or previous civilizations enhancing the historical heritage. In addition, craft seeks to promote the use of local raw materials, techniques for transforming materials through processes where manual work predominates and allows the dissemination of these techniques from generation to generation, seeking sustainability in the region where they take place.

This is quite important, as it gives the product a unique personality and great cultural value that can be seen beyond a utilitarian or decorative function, even allowing it to gain the character of a work of art (Muñoz de Gaviria, 2013). Crafts also allows for the possibility to promote the design of new products and the incursion of design as a disciplinary area that allows including market analysis, trends and new incursions into production processes.

With nopal, its by-products and wastes, they are a rich source of long fibers (hard or soft) that come from the vascular system of leaves or stems that can reach up to 5 meters in height (Finck-Pastrana, 2014); and short, which come from seeds or fruits (González & Ramírez, 2007). The architecture of the internal structure of the nopal, Figure 8, is a rich source of inspiration for product design. Biological processes exhibit ideal characteristics for creative processes, because of their ability to adapt and develop while they remain alive. These characteristics have been used in design studies and projects, either in the initial stages where the problem is identified, in the translation of the design requirements into forms, or in the last stage of inserting the object in use (Patiño Mazo et al., 2015).

Figure 8. Structure of nopal wastes got from different parts of the plant (own source).

Materials can be a source of inspiration in engineering based on their properties: dimensional changes, water absorption, thermal expansion and contraction, modification due to contact with chemical substances or mechanical effects. But also in design, since they can transmit emotions and sensations to the user, just as Mike Ashby mentions in his book "Materials and Design. The art and science of material selection in product design" (Ashby & Johnson, 2014).

This opens the possibility for inspiration and creation of artistic works, since the importance of finding new material sources for the creation of art cannot be ignored (Ashby & Johnson, 2014; Bernárdez Sanchís, 1994). The materiality against the conceptual load (idea) can be expressed as "the fight because of which the form overcomes the resistance opposed by the matter" (Bernárdez Sanchís, 1994). This statement reinforces the importance of mastering the technique of obtaining and transforming nopal waste.

The materials express the potentiality of the work and the artist imprints his own way of feeling and thinking on the materials. Materials, therefore, reflect life (Bernárdez Sanchís, 1994), and that is why the nopal is described in Artes de México as "a melancholic, ritual, emblematic and paradoxical plant, which offers us the blood of its leaves, the water of its fruit and the edge of its thorns as guides to enter the arid roads of Mexico" (Bermeo et al., 2002).

This is, without a doubt, an opportunity for endogenous development, not only for the municipality of Sonsón but also for Colombia's economic growth.

Contribution to the socioeconomic development of the region

Including the waste generated in a previous life cycle in the production of a new cycle is a way that offers sustainable options, favoring the circular economy, generating benefits both economically and environmentally, reducing the negative impact that is closely related to the last stages of the life cycle such as final disposal.

In 2015, the United Nations defined a list of goals to eradicate poverty, protect the planet and ensure prosperity for all (Naciones Unidas, 2021). They called them the Sustainable Development Goals (SDG). These are framed in the agenda for sustainable development, and each one has established goals to be fulfilled during the next 15 years. Our task is to work in cooperation between governments, the private sector, and civil society, to respond to these requirements.

In this way, and with a first attempt at cooperation between the private company, the public sector, academia and enthusiastic civilians, it is proposed to build and develop a museum exhibition and invite different artists to interpret the material from the nopal residue from the individual perspective of each artistic identity.

Museographic exhibition: The nopal, weft and permanence

This exhibition summarizes more than a year of work between a multidisciplinary group, where time, ideas, conversations and creativity made it possible to make the empirical knowledge of a rural woman, Ana María Orozco, an opportunity for union between different sectors, to build, to transform and to contribute through the use of nopal waste, Figure 9.

Figure 9. Workteam and Sonsón's mayor and agriculture secretary on the exhibition opening (own source).

The nopal

At the beginning of the exhibition, Demonte Studio, with its botanical installation, shows the fertility of the plant through its fruit, the fig, and the stunning beauty of its leaves, Figure 10.

In his curatorial text, Miguel Mesa Posada immerses us in the exhibition alluding to the georgic cactus. "Georgic is a poetic genre that evokes the rural, as expressed by its Greek origins ge=earth and ergon=work or labor. In this genre, the country life and the poet's native terroir are praised, glorifying his or her labor. It has a traditional accent that merges with lyrical inclinations", Figure 11.

Miguel also highlights the importance that "this exhibition does not seek to fill any historical lacunae, but to explore the aesthetic possibilities of what can be derived from this plant, so characteristic of the American landscape, but so recent, for some, in the antioqueño panorama. This

Figure 10. Demonte's botanical installation at the entrance of the exhibition (own source).

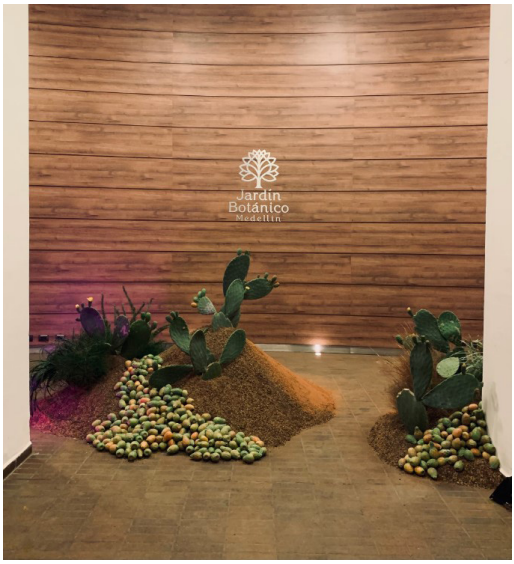


Figure 11. Assistants to the exhibition interacting with the curatorial text of Miguel Mesa Posada (own source).

exhibition suggests a georgic around nopal, this crop from Sonsón that is making its way into the agro-landscape of the region formerly known as "Corn's Jerusalem""

The invited artists who brought this exhibition to life with their creations, allowed the public to be taken into a journey that describes with great sensitivity the role of the nopal in Sonsón.

The weft

The documental video produced by Seis Audiovisual and directed by Santiago Marzola, Figure 12 , which carry the same name of the exhibition, reveals the testimoni of fig farmers and the construction that Ana María Orozco had built with nopal wastes through the years. The journey continues through the weft with the curatorial text by Mariana Peláez Rojas, where she explains that "The weft makes tissue possible when it crosses the warp on a loom, it is also part of the stories when it connects events in a narrative"; "The fig tree crosses family history as the weft crosses the tissue. Like the plot in the narrative, it connects the stories of the families of a sector of the municipality of Sonsón and offers them an identity, their story, in which they are owners of the strength, the resistance and the tenacity of enduring a work of habit and a life that avoids the poverty with the generosity of a plant that brings food to the table every week".

This allows us to continue the journey through the portrait photographs of nopal growers that Daniela Cortés exhibits; as well as the botanical illustrations where Pablo López interprets the colors, pollinating animals, and beauty of the plant residues. And she closes by saying: "The nopal is a weave of living tissue, peasants, animals, stories."

Figure 12. Fragments from the documental video Nopal, weft and permanence (Marzola, 2021).

The permanence

Finally, Santiago Marzola brings the public to the closing of the exhibition with his text where he defines the word permanence as "something that perseveres and is constant. Which is durable and sturdy", referring to the use of nopal and waste from different parts of the plant. He also says in his text that "...it can be said that something is maintained when it persists and does not change, but the actual way that something is perpetuated is through memory." to carry the public to the products and artistic works that gave rise to the engraving work of Ángela María Restrepo, jewelry work of Helena Aguilar, Brvtal Objetos and Ana-Taller sin Borde, the luminaries of Ana María Orozco and Lina María Agudelo, and the installation of artwork by Santiago Marzola, Figure 13.

Figure 13. Detailes of some products exhibited during the museographic exhibition: luminaires and jewerly (own source).

He concludes by saying that this work allows the public to testify "... the transformation of the material what allows us to extend the life of the plant and expand its possibilities towards an aesthetic and experimental field. We see how different parts become pieces interpreted by different creators who play with their unique characteristics: lightness, resistance, translucency and its own natural condition, to make it co-exist with the poetic of the material".

Conclusions

The information shown in this document, represents an opportunity to promote the development of the region by taking advantage of the waste generated in the production of figs, as well as the benefits of other extractable by-products of nopal such as leaves, mucilage, fibers, among others, that enhance the promotion and comprehensive use of the entire plant, raise awareness in the community, particularly in the municipality of Sonsón, about the uses and applications of nopal in new products which are engines of socioeconomic development in the region.

The agro-industrial waste generated during fig production will be a starting point to propose strategies from the circular economy, since they are usable raw materials, allowing the generation of new life cycles through the development of new materials, products and services. This will allow a positive impact on the population of Sonsón, not only economically through the products, but also culturally, with the production of artistic works, valuing the waste produced, relating the materiality of the products with the art, respecting and maintaining the identity of the region, and craft techniques.

The exhibition sought to promote projects around the use of the plant that have been developing during the time of research. The artists

invited to be part of this very first outreach space found formal richness, inspiration, and function in the raw materials that nopal wastes offered.

Finally, the possibility of building shared knowledge about the benefits of using these nopal waste is opened, and motivate community members to develop enterprises based on the findings of uses of the material, from the insertion and transition of adaptable technologies, for the strengthening of Antioquia's agriculture, specifically the municipality of Sonsón, Antioquia, through the complete optimization of the nopal, for the generation of new products, by-products and diverse applications that can improve the quality of life of the inhabitants of the region.

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Products Validation in the Design Project and Scopes in an Online Educational Environment[1]

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Abstract

This article gathers the results of a research on the project's pedagogy, which, starting from the analysis of the contemporary theories about it, presents their common horizons to contrast them with results got in previous research. Therefore, through a critical approach it was proposed to explain terms used to refer to the design project and validate modifications to a project method proposed in the education of designers. That was necessary to adapt it to the online workshops produced by COVID-19 confinement in 2020. Those modifications focused on its

[1] Research Project: Lineamientos para una pedagogía del y para el proyecto en contextos de enseñanza las disciplinas proyectuales. Rdo: 583C-05/20-35

most critical activity, in-process product validation, which is essential to evaluate products' environmental and social sustainability and the training in responsible design practice.

Keywords: Design, pedagogy, project, validation, online connection.

Introduction

This paper shows the results of the research study Lineamentos para una pedagogía del y para el proyecto en contextos de enseñanza las disciplinas proyectuales. It was developed by areas in Proyecto e Innovación and Crítica y Proyecto (Project and Innovation, in Criticism and Project) of the Estudios en Diseño (Studies in Design) (GED, for its acronym in Spanish) and Estudios en Arquitectura, Urbanismo y Paisaje (Studies in Architecture, Urbanism and Landscape) (GAUP, for its acronym in Spanish), groups of the Pontificia Bolivarian University (UPB). The phenomenon, the projectual activity, tooked place in workshops of the professional cycle of the Industrial Design (IDES) undergraduate program at UPB. The aim was to validate the modifications to a method[2] linked to the training processes of designers. This method includes six moments of project actions that develop around two parallel axes: projectual axis and research axis[3] (Mesa-Betancur y Correa-Ortiz, 2018. p.502). These actions gather activities and tasks to be carried out throughout the project, unfolding design and research methods and resources to provide project decision for every stage[4].

2 Methodology is defined as a strategy for the array of methods.

3 The initial inquiry as part of the research for the project (Mesa-Betancur y Correa-Ortiz, 2018. p.501) is the most common. However, during the process, there are activities that relate the research to different project moments (Mesa-Betancur, 2019. p.2), including the expected performance validation of the products.

4 At Portsmouth, United Kingdom, in a conference on design methods in 1967, Geoffrey Broadbent (Broadbent et al., 1971. p. 22) stated that some attendants, especially Markus, viewed the design process as a course of events leading from the project idea to its

In 2020 because of the pandemic and the confinement, it was needed to virtualize the project workshops. Thus, IDES School launched the academic project Virtualización experimental (Experimental Virtualization), which included ongoing research. The assignment was to explore the validation of the design project products in an online educational environment and apply them to one of the program's subjects[5]. It was an opportunity to contribute to the research whose objectives aim to describe the project pedagogy guidelines that include the project praxis and study based on a theoretical analysis of the project. To expose the shared perspectives, compare them with previous research results. And to validate the suggested project method (Mesa-Betancur, 2019) and explain the terms and concepts used for the design project description using a critical approach. As preliminary results, we present the methodological, theoretical, and conceptual frameworks used, the disambiguation of terms, the methodological validation, and the findings regarding their extent in an online educational environment for the designers.

Methodological framework

During the research a documentary review was carried out to identify sources. Then, the selected sources were classified, followed by a categorization for their analysis and a critical verification. The Educational Action-Research by John Elliot (2009) was used to validate the method

realization. It is performed either information, analysis, or summary «intervals» as a part of a "Decision Sequence" that links the "Operation research" to the project.

5 In the UPB IDES undergraduate curriculum, the main subjects are educational spaces where collaborative team projects are developed, located in different environments of professional practice in order to contextualize the skills of the designers in formation. Four components are synergistically structured around the project design: theoretical, thematic framework; observatory, research for the project; feasibility, project, and its products management; experimental workshop, design and formalization. This structure allows methodological development by articulating research, design, and management scenarios (Mesa-Betancur y Correa-Ortiz, 2018. p.502).

modifications in order to analyze the students' design process. In the follow-up the students used the adjusted project method in their design process. One researcher served as an experimental workshop teacher and the other as a feasibility teacher. The first one kept a field diary to report the course events, considering the strategies used, the development of the practice, and the actions and effects of the involved actors. The second monitored the adjusted validation processes. The students used the Estrategia de explicitación (explicit strategy) (Mesa-Betancur and Mejía-Quijano, 2011. p. 178-179) to record the mismatches perceived in their process. Finally the information gathered in the classroom was collected, classified, and systematized, and semi-structured interviews were conducted with the students who were part of the experience. The comparison of this information allowed us to draw the conclusions mentioned above.

Theoretical framework

It was reviewed twelve design methodologies (Broadbent et al., 1971), eight projectual theories (De Sola-Morales et al., 1971.), two Project Theories (Piñón, 2006, Argan, 1969), five design methods (Gero y Kannengiesser, 2014; Cross, 2002; Pahl y Beitz, 1984; Jones, 1982 and Archer, 1982), one design method (Llovet, 1981) and documents on projectual research, modeling and testing (Tappan, 2012; Balderrama and Flores, 2018; Sathikh, 2019; Rodríguez-Parada, Romero and Domínguez, 2016 and Villafuerte and Sossa, 2019). Research-project links were traced and evidenced, especially the validation of products during the formalization phase, and the terms with which they referred to projectual issues.

As Peer Sathikh (2014. p.1) states, from the former work in the 60s and 70s about "Projectual Research" focused on its methods and processes a variety of terminologies were (and still are) produced to referred to

these[6]. The conducted review, both in the architecture and industrial design areas, proved that the authors refer to the assessment of the finished products (built or produced) or in its design process, with terms such as evaluate, assess, validate, verify and feedback of feedforward. Although, the meaning in which they are used depends on the author.

The relation between project and research was first highlighted in Progetto e Destino by Giulio Carlo Argan (1965, pp. 21, 27, 70). It states the need to verify step-by-step the "project-process" and the succession of its intentional acts so the "project operation" is critical, rectification and address for future action (p. 56). For Argan, it is crucial to verify the intentionality of the actions and the time in which they occur. Other authors suggest this relation differently.

In 1966, in architecture, Manfredo Tafuri, Gabrielle Scimeni, Luciano Semeran and Guido Canella (De Sola Morales et al., 1971) also refer to the action of verifying. The latter has to do with evaluating aspects of a constructed building as a product of a project, among others, its validity and formal objectivity, its economic-social impact, the veracity of the data deployed in the process or its historical validity. Therefore, Anthony Ward, Raymond G. Studer, M. L. Jane Abercrombie, Geoffrey Broadbent and Amos Rapoport in 1967 (Broadbent et al., 1971) alluded to projectual actions as a feedforward, verification, or evaluation to refer to the assessment of the project products (constructed buildings) and as a reference for future processes. Rapoport clarifies that the selected method should consider the success achieved when the produced designs are assessed (p. 319). Helio Piñón (2006) does not explicitly mention these activities during the projectual process. He only states that his students are not only "devoid" of tools for creativity but also lack "judgment capacity to assess their proposals" (p. 64).

[6] During the review, the studies and documents centered on the architectural project and its methodology after the 70s were limited.

In design, Gerhard Pahl and Wolfgang Beitz (1984) as well as Nigel Cross (2002. pp 14, 39, 57 y 155) point out the need to verify the technical and economic aspects of the product at the detail design phase. Cross includes in this verification (before the final version) for manufacturing tests with prototypes and evaluation of results against design criteria, the checking of requirements through weightings set by the members of the work team. Bruce Archer (1982) also talks about designing validation tests for the last phase; however, in 1967 (Broadbent et al., 1971. p. 208), he stated the need to assess and evaluate the product in process through simulations of its behavior to report project decisions. Christopher Jones[7] (Broadbent et al., 1971. p.392 and Jones, 1982. p. 130) points out that it is necessary to validate and test the product during the process and simultaneously verify the validity and truthfulness of the data used for the decision-making[8]. Recently, Silvia Villafuerte and Liliana Sosa focused the validating, assessing, and verifying actions for IDES projects.

Back in the Architecture field, despite the importance of the critical assessment over one's interpretations in specific projectual moments mentioned by Alberto Samoná (De Sola Morales et al., 1971. p. 177-178), the evaluation is performed against the experience of the built. Thomas A Markus (Broadbent et al., 1971. pp. 235, 241, 250-252, 254) is the most specific regarding predicting results during the projectual process. He points out the importance of evaluations through assessment and tests whose results are "decision factors" (p. 235); without discarding data derived from the assessment of buildings in use, he states the models produced during the process must have enough details to test them. On a radical side, Sydney A Gregory (p. 227) stresses the need to find a single evaluation method for alternatives during the process, enabling

7 The document is a guideline for validation and verification more than a design framework.

8 This last aspects (verifying) is crucial for Jones (1982), who, compared to Cross (2002), states the importance of empirical evidence over consensual weightings. Jones' and Cross' theories came with many thoughts of the late 20th Century on the IDES project.

establishing their suitability to the function, costs and manufacturing process in terms of effectiveness and efficiency.

As another no less important aspect, Ward states that tension between subjectivity and objectivity has existed among the design methodologies concerning the role of Rapoport's "subjective assessments standards" or the subjective interpretation of the "objective" phenomena (p.16); in short, the designer decides (most authors agree). For instance, for Broadbent, the designer's judgment (p. 412) is crucial because there is no aim mean to establish the qualitative. It has been observed that this old tension could be resolved through the objectivity-objectification dialectical by including as many tools as possible. All this to achieve the objectification of a process in whose subjectivity has a prominent role. However, we agree with Markus when he points out that the "evaluation techniques" applied to the project lack development and more research and experience will be needed to make them play a strategic role during design. But we disagree when he states that at present, they are merely tactical tools "a testing device to ensure that catastrophic failures will not occur" (p.254), which is already a major outreach.

In summary, most authors agree that, since the classical project and until the twentieth century, the element of judgment on the quality of the project was the level of perfection or beauty achieved by the product. However, in contemporary times, the value of the project is determined by the rigor of the process (Mesa-Betancur, 2017. p.51, 53; 2018. p.67, 94).

Conceptual framework

To understand the adjusted method, the following terms are introduced: *design problems, dimension, requirement, product, model and prototype;*

and the terms validation and verification and simulation and simulacrum are clarified.

In the first place, a *problem*[9] or design approach is understood as establishing needs or opportunities in a contextual situation that can be addressed by design. It involves inquiring, defining, and describing a phenomenon as a tension related to an assignment or an initiative. The design problem synthesizes information that situates the project and determines actors whose "needs" contribute to clarify its intentionality and design requirements (Mesa et al, 2019. p.6). (Mesa et al., 2019. p.6).

Such requirements[10] connect the purpose of a product with its observable or measurable performance, quantitatively or qualitatively, as a mediator in a practice; they understand its relevant features and characteristics (Mesa-Betancur, 2019. p.1) and guide the decision-making during its formalization. Between the desirable and the necessary, between the workable and the achievable, and between the aspirations and requirements, they vary. They can be seen as performance requirements of every aspect of the object and classified as restrictions when they cannot be changed. When they represent goals to be achieved can be seen as aims and as variables when they may change during the process (p.7). As a formality, the requisitions must be clearly and precisely written, setting a project action that rests with a characteristic of the object, its purpose, and a validation method.

Dimension is a point of view from which an object, to which particular characteristics are recognized, exhibits a unique feature (Prieto, 1988.

[9] For the design problem term, previous research results were contrasted with: Mesa-Betancur et al. 2019; Mesa-Betancur y Correa-Ortiz 2018; IDEO, 2015; Gero & Kannengiesser, 2014; Pahl y Beitz, 2013; Ullman, 2010; Cross, 2009 y 1996; Maslow y Lewis, 1987.

[10] The requirement term is based on: Mesa-Betancur et al. 2019; Mesa-Betancur y Correa-Ortiz 2018; IDEO, 2015; Gero & Kannengiesser, 2014; Pahl y Beitz, 2013; Ullman, 2010; Cross, 2009 y 1996; Maslow y Lewis, 1987.

p. 30). The UPB IDES program defines five project dimensions, points of view from which an object to be designed must be considered. In first place the interpretative dimension, *aesthetic-communicative*, which includes the way how perception influences (becomes effective) over the impact of the object and assess the communicative support regarding the feature of the form. The instrumental dimension, *functional-operational,* incorporates how the function impacts the product operation and assess the formal solution that makes them possible. The material one, *techno-productive*, includes how the technique influences the production and assesses the feasibility of a proposal based on the chosen processes, available technology, and qualities and limits of the materials. The management dimension, *economic-administrative*, incorporates how the economic factor impacts the project and product management and assesses the coherence, relevance, efficiency, and effectiveness of resource management and the selection of the distribution and procurement channels for products. Last, the ideological dimension, *historical-political*, covers how the historical moment affects social action and assesses the project regarding ethical, aesthetic, and political and in a democratic and the rule of law context (pp. 30-31). In every dimension, requirements for the formalization of the products are established. The *product* is the result, not only on the physical aspect, of a work, process-operation both material as mental or intellectual. Thus, it can be tangible or intangible. In the design area, the tangible results are called "goods" and the intangible ones "experiences" or "services."

In the design field the products are materialized for their assessment as *models* or *prototypes*. A model is an experimental scheme of a more complex real object made to ease its comprehension and study its behavior. It can be physical (typically in scale) or virtual, total, or partial, and it works as a reference for the prototype. In the industrial context, the former is the first product of a process in actual conditions that act as a "model" for manufacturing the following products that would be its copies. It's used so its developers can test it and remark on

potential flaws or shortfalls. Once tested, analyzed, and adjusted then, mass production begins. On the educational scope, what can be called "prototypical" models (related to the prototype) or 1:1 test models are built. They replicate as many design characteristics as possible, so its performance can be validated regarding its requisitions. However, not all aspects could be validated and, sometimes, just a few of them.

The term *verification* carries further elucidation and validation, related to the projectual *assessment*, *simulation* and *simulacrum* as a test scenarios.

Verification[11] is a level in which we evaluate or corroborate the veracity of the projectual process, the methodological coherence and the concrete data and evidence that support or are the reason for the decisions taken during the process. In the educational area, the verification instance and evidence of verification is the project report.

Validation[12], meanwhile, is a projectual activity where first it is confirmed that a product corresponds to a problem stated as a projectual

11 For Jones (1982, p.57), to verify is to ensure that the sources are reliable and adequate; that the data register and the tool usage has been correct; that the projections have been accurate, in short, that they are truthful and applicable. According to Yadira Corral (2009), validity refers to the degree of reliability of the information for the decision to be made (p. 230). For Studer, verification is carried out on the built products and consist of knowing that a problem has been solved in practice (Broadbent et al., 1971. p. 123), it involves verifying the resulting system, its behavior and relation to the environment. He states that the design framework has been ignored in the design* activity. Howbeit, Cross (2002.P.14) sees verify in an immediate sense to validation, namely means assessing design proposals through weighted lists where goals are compared against requisitions (p.46). Pahl and Beitz recommend verifying the technical and economic aspects during the detail design stage (p.39).

12 Gero and Kannengiesser indicate that to evaluate (next to validation) is to evaluate the design solution based on the established rules by comparing the behavior of the solution against expected behavior (p.11).
Similarly, Villafuerte and Sosa (2019) point out that according to CIPAM (2006) (by its Spanish acronym), "prospective validation" provides documented and reliable evidence that a tested product will behave within the established specifications (p.19). This should be done at different phases of the process and with different approaches, giving particular attention to sustainability. According to them, the benchmark that can be validated should provide data that confirms the validity of the proposal and reduce its risk of failure (Villafuerte y Sosa, 2019. p. 195, 197). Lucía Rodríguez, Luis Romero and

situation. And its characteristics are relevant for its use and suitable for its material and symbolic function. It matches the expected benefits of people who do a practice in certain context. Second, it ensures that the products in their materiality can withstand given working conditions with no unexpected wear or functional mismatches, meaning the life cycle. Likewise, it assures that their production is achievable under the named conditions and that their distribution and procurement are suitable to the target audience. Last, it is confirmed that the product complies with the established rules and the design criteria regarding social and environmental sustainability.

In the academic field the most common validations are those based on the representation using drawings and analog or digital models[13]. Validations are based on the data comparison; physical trials using "prototypical" models; and the socialization of final or partial results as an academic level of validation for the project scope and the development of students' competencies. To conduct them, protocols are established, where the variables considered or the expected quantitative or qualitative values, the suitable processes, the resources, and a time frame are determined. The gathered information is systematized and analyzed, and the summary data point out the relevant modifications to the products (Mesa-Betancur y Correa-Ortiz, 2018. p. 503).

Manuel Domínguez (2016.p.1-2) and Omar Balderrama and José Flores (2015.p.26) agree to it. Nevertheless, for Jones (1982), good design is the optimal solution to valid needs in particular circumstances (p.159). Aspects or characteristics of a product must be validated during at different design phases while combining methods (p.130). Trial situations with the actual users should also be chosen to distinguish valid and invalid solutions (p. 131); to be clear about their performance in a task, and to adjust them based on the result (pp. 196-198). Cross (2002), on its behalf, states that validation is performed during the final design phase (p.43). For him, it consists of checking requisitions and comparing alternatives (p.47); he gives particular attention to the cost-benefit value and perceived value (p.160). He states that Archer (1982) identifies a final development phase where prototypes are made, and product validation tests are designed before manufacturing (Cross, 2002. p. 35).

[13] Sathikh comments similarly (2020. p. 7).

In summary, the project is verified as a process and the design products are validated as one of its results.

Continuing, validations that require testing are performed through *simulations* or *simulacrums*. In order to distinguish both scenarios, these terms were compared with those from other disciplines by adapting them to the projectual process because of their similarity. First, simulations are tests that are carried out in a controlled environment (physical or virtual) of the designer's work context. They are also known as "desktop exercises". Designers and other actors may substitute for those in the real context. They are also based on the conjectures on failure risks, performance potential, affective or sensorial responses, perceptions, and impacts, among others that are included in the validation protocols.

Simulations are used to strengthen decision-making processes at specific moments, which make them strategic and tactical tools for project and products management. The simulation dynamic is based on a protocol that establishes the events that may occur chronologically in an actual context, and this sequence is replicated in a chosen mean for the simulation. The exercise control and the analysis of the resulting data strengthen the decision-making. Simulations can be classified as partial when parts or specific characteristics of an object-product are tested and total when it is tested in all its dimensions.

This type of exercise is an efficient pedagogical strategy for the development of projectual skills and capacities and expertise that supplement the formation process by allowing a better understanding of a projectual situation, knowledge, and experience that contribute to its professional practice.

On the other hand *simulacrums*[14] are practical exercises that represent a situation as close to reality as possible (INDECI, 2014. p.1). Therefore, it is a way to test a design object in context. During its planning, it is important to ensure that there is correspondence with the daily life of the actors and that the exercise takes place in the intended context. A simulacrum is relevant when it is necessary to test a goal performance in context or the perception and impact on people because of its presence or during their engagement.

It is developed by activating a placed activity, from which the object is the mediator, as if it was happening in real-time and where its participants play their usual role. Hence, the protocol making requires strict control of time, and it is appropriate to have carried out previous simulations to optimize the activities and their monitoring. They are classified according to their scope or complexity. According to their scope they can be specific when they test parts or general when they test the product. In terms of complexity they can be simple if they are performed in a single scenario and aim to assess basic interactions. Complex if interaction variables test as many options as possible. And multi-scenario simulacrums if they are made in different locations (p.10). For this reason, its complexity determines the resource mobilization and logistics, the number of people to control it, and the record of its development and process assessment.

Similarly to simulation, simulacrums have a high pedagogical value, given that they allow for to strengthening and testing of useful skills (besides knowledge, capacities, and expertise) in the decision-making process regarding the modifications to the designed products (Martínez Rueda, 2016. p.9).

To summarize, *simulations* are conducted under a controlled environment while simulacrums are carried out in the named situation in

[14] This term is supported in INDECI (2014).

the project approach (INDECI, 2014. p.2). Regarding its costs, the former can be conducted with few resources from drawings, study models, or digital modeling, whereas the latter requires more resource investment; for example, prototypes or 1:1 test models are needed. Now, *simulations* are easy to plan and execute compared to simulacrums. They only entail information management and are easy to control (they depend on the skill to manage the means). However, its scope is limited and demands analyzing and reading properly for decision-making. *Simulacrums* involve carrying out protocols in context. They are complex to control and require attention to detail before, during and after the test. Still, its scope is vast, and the results are more reliable and clearer.

As a resemblance, they are correlative to the formalization process. They allow us to see the product's potential and to inform the projectual decisions. They strengthen teamwork and cooperation between the involved actors (Martínez Rueda, 2016. p.10). Contribute to the consolidation of projectual and critical competencies for responsible professional practice.

Results and analysis

Once the frameworks for the validation of the changed method have been clarified, we describe the execution of the projectual[15] activities in different moments, the way they were developed in an online educational environment and their scope. Although we mentioned six projectual actions, neither the total of the involved activities nor all their tasks were reported, only those related to product validation.

[15] The validation activities were only applied to industrial design projects. In the review carried out at the School of Architecture, there was no evidence of them being used, it seems as Beatriz Colomina (2010) states that architects act as if their buildings are images and do not care how people occupy them (p. 120).

In the first moment, concerning the contextualization of the assignment or the initiative that drives the project, the projectual action one also known as initial inquiry was developed. A reading of the context in which the order was placed and a state of the art of related products available for procurement were carried out. At the end, conclusions for the product proposal were drawn by relating a situation with its impact. Based on these conclusions, the approach (design problem) was developed.

Starting the projectual action two "conceptualization," the first activity, building a product proposal (descriptive text) responded to the described situation in response to the assignment or initiative.

This description incorporated the object characteristics in terms of the interactions, perception, and impact on people when using it and the reason they would have for doing so.

With this in mind, we built a reference framework based on the state-of-the-art objects, but not only, that presented characteristics that could be assimilated into the proposal. As a synthesis, a project name was given as a linguistic reduction (Mesa-Betancur y Correa-Ortiz, 2018. p. 503, Llovet, 1981. p.31-33), which focused on the process of idea-creation intentionality.

The product approach and proposal were the first validation activity. The arising situation was reviewed to make sure that the delimited was presented as described and the proposal to validate its relevance. Protocols were changed for the online environment. Structured interviews[16] and surveys with open-ended questions were used for data collection. The fieldwork was carried out through video calls and online applications[17]. In order to systematize data, answers were transcripted

[16] Soonthorndhada (1989) was used as a reference to develop interviews.
[17] In this case Google Forms was used.

and codified and analyzed through a comparative matrix[18]; last, the findings were plotted. They were not much different from those gathered in the classroom. Although, participant observation usually used was not conducted because of the confinement. Instead, students resorted to observing their own domestic environments (not necessarily consistent with de projectual situation) and contrasting them with the other findings got to identify differences and similarities. It allowed us to aware the importance of this task to apply it in a future situation. As a synthesis, a requisition matrix was developed, and it included its dimension, type, variable considered, and the value or expected condition in its validation.

At the beginning of the projectual action number three, the formal synthesis of the design product, three activities tooked place: the development of a "formal hypothesis" (Mesa-Betancur y Correa-Ortiz, 2018. p.505; Mesa, 2018. p.92; 2017. p.52; Argan, 1969. p.38), the production of options and alternatives, and its assessment (Jones, 1982. p.34). During these, the initial conditions of usage and operation of the proposed object were focused, and dimensional control tests and postural simulations were conducted; they are both validation activities. The designs were compared with the standardized data, dimensional standards based on the percentiles[19] and close at hand products that, because of their characteristics, worked as references.

In the former design methods were used to analytically compare the proposed dimensions against the chosen standard ranges for potential users. Starting from exploratory scale drawings, experimentations with study models[20], and articulated mannequins. During these simulations it was compared the views of the object considered enough, based on

[18] Baranger (2009. p. 13-15) was used as a reference for the data matrix tool
[19] In this case, Panero and Zelnik's (1996) text was used as reference.
[20] The value of study models in these early validations is stressed by Sathikh (2014. p.6).

an intended sequence of usage, against the ergonomic standards of reference (see image 1)[21].

For the latter existing furniture (or part of them, such as cushions or structures) and another close at hand elements (like boxes, boards, cardboards, among others) were used to "build" in an intuitive-experimental way a volume simulated that would have close characteristics to the proposed object (dimensions, angles, etc.). And on which to conduct posture trials with people who had similar characteristics to the users considered. The tests were recorded in photographs and videos for analysis, the observation was supported by structured interviews with the participants. The students performed the experience in their homes (see image 2). These validations proved to useful not only for their results but also motivationally. They realized the products' dimension and usage potential they objectified their designs and appropriated its project. During this time, validations were also performed. They assessed the aesthetic perception, the correspondence with the existing rules and the distribution channel, and the procurement proposed. In the first one, the product's legibility was validated using structured interviews and surveys with closed and open-ended questions accompanied by design drawings[22]. For the second validation, a first approach to the correspondence with the existing rules and the product was revised[23], in progress. Last, the characteristics for the proposed channel were assessed in a consumer journey map[24] and a comparative matrix with products of similar channels identified in the state of the art. (see image 3).

[21] All images were taken from: Rodríguez, Franco and Rodríguez (2020) Bitácora Digital de proyecto del Núcleo Proyecto y Domesticidad.

[22] Unlike production designs, design drawings are those proper to projectual development. They can be as formal as needed, but their purpose is to build the product, assess it, and make decisions for its modification. (Dittmar, Rogers y Ginis, 1980).

[23] The ICONTEC standards 1440,1987, 2306, 2514, 2867, 50141, 5431 (ICONTEC. 1978, 1990, 1987, 1989, 1991, 2002, 2006) were compared.

[24] The analysis was based on Angrave (2020. P. 13-19).

Image 1

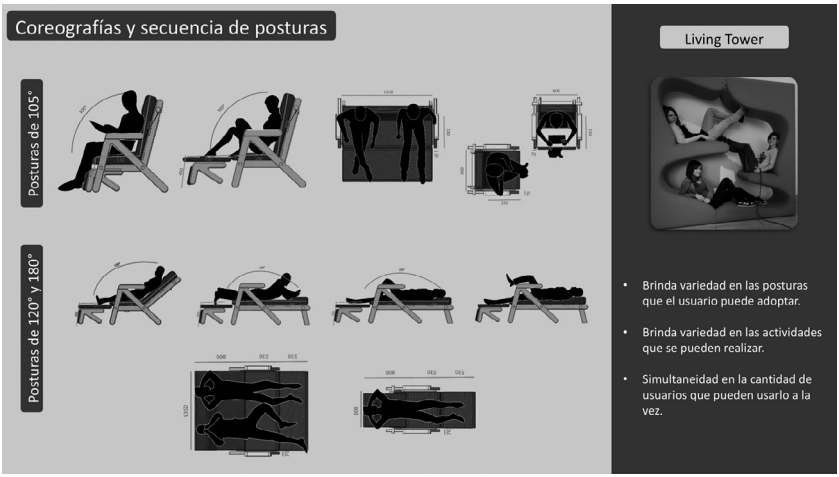


Image 2

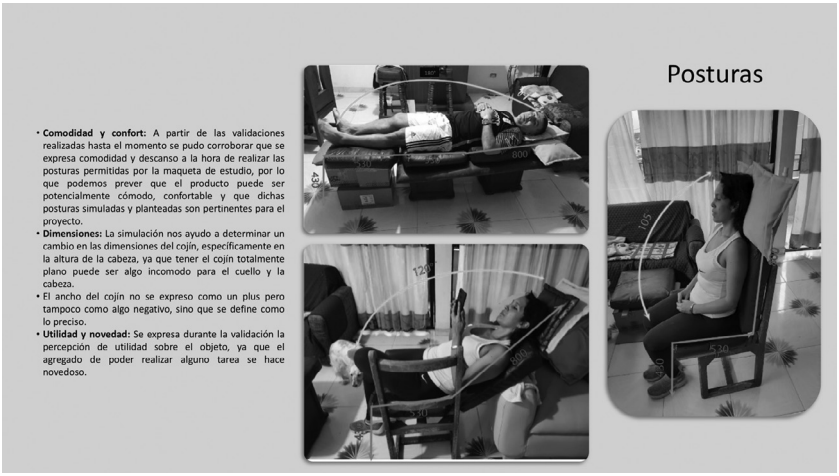
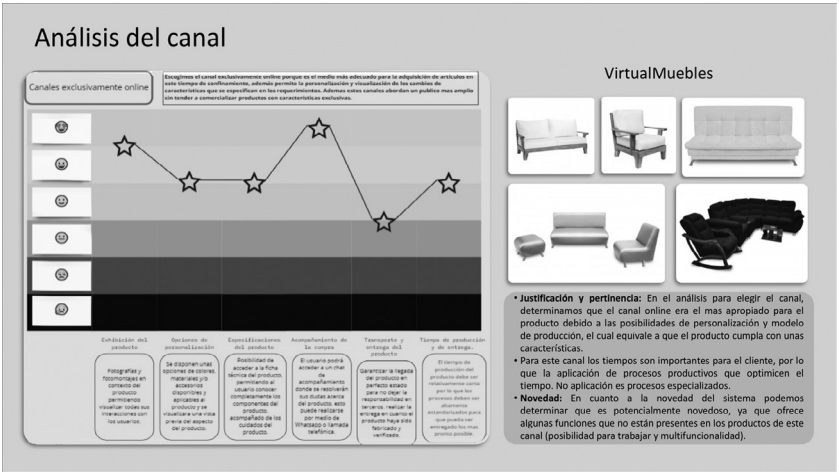


Image 3



The simulations and analyses performed were suitable and allowed to inform the modifications.

In the preliminary draft stage corresponding to projectual action four (the object synthesis of the design product) we got a more informed product with adequate characteristics to carry out tests focused on its operation, materiality, and production. The first complete progress of the Project Report (Informe de Proyecto) (Mesa-Betancur and Correa-Ortiz, 2018. p. 506) was presented as a verification level.

At the beginning of action five, at the contextualization of the object-product of design, we clustered the changed requisitions during the process based on the required test for their ultimate validation. Also, we designed testing protocols according to whether they required simulations or simulacrums.

Since only simulations could be performed, since simulacrums required a prototype or "prototypical" model that was not within the possibilities, we proceeded to the construction of detailed digital and physical models in the scales recommended for standardized tests[25]. We used Fab Studio, partnership UPB-Rhino3D Colombia, and the accessible remotely software for the first models. For the other models, students developed 1:5[26] test models (each student built one) with materials accessible[27] to their location, like the product.[28]

The validation tasks were organized in a matrix for test protocols[29], the aspects to be validated of each requisition, trials' step-by-step, the resources, the variables to validate, and the expected or guessed value. The physical models allowed stability and performance tests, and the digital ones allowed different CAE (computer aided engineering) analysis. Resistance, structural behavior, and manufacturing possibilities were the last ones that focused on techno- productive aspects. Nesting analyses were also conducted, where necessary, for the production variables. FEA[30] (Finite elements analysis) models were used for the structural trials (see image 4), and DFM[31] (Design for Manufacturability) and DFA[32] (Design for Assembly) analysis matrixes were used for productive feasibility (see image 5). Each validated aspect, the involved people, the tools used, and the evidence and the findings were recorded in another matrix and finally synthesized in analytical graphics. These allowed us to

25 Omar Balderrama and Jose Flores (2015.p.26) state that designers value ergonomics and usability, appearance and acceptance of their models; they check the functionality of mechanisms, volume-area relations, limits of endurance, or they simulate materials.

26 Sathikh (2014. p.7) points out the use of models for this type of test.

27 Sathikh (2014. p.7) states that for physical testing if its scope is to be improved, the model must be built with the same materials as the final product.

28 This situation was because some of the team members were geographically dispersed, and the University's model and prototypes laboratory was closed due to the pandemic.

29 Rodríguez, Romero and Domínguez (2016) state that matrices for validation allow us to disaggregate factors (information) and turned into (data) technical, physical or visual characteristics.

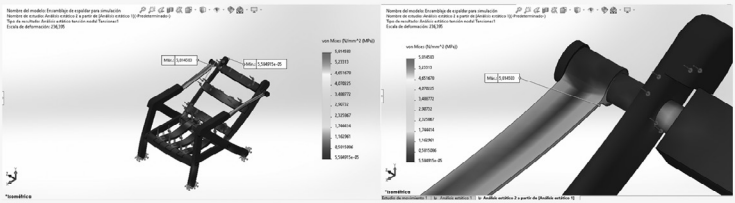
30 For this analysis, we used Solid Works software licensed by UPB and accessible remotely.

31 The analysis was based on Anderson (2004. p. 29-32).

32 The analysis was based on Boothroyd (1980).

Image 4

Resultados de tensión



En los resultados se evidencia qué, el mayor esfuerzo se presenta en la correa, este esfuerzo esta por debajo del límite elástico del material por lo que se concluye qué la pieza no fallará ni afectará la funcionalidad del producto. En cuanto a los travesaños frontal, posterior y del espaldar, no se evidencia un esfuerzo superior al que puedan soportar.

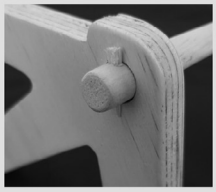
Image 5

DFA

- Para facilitar al usuario el ensamblado de la silla, se propone entregar las piezas del asiento y el espaldar ensamblados, de este modo se reduce también el tiempo de ensamble.

- Para el ensamblado de los largueros del asiento y los travesaños del espaldar, se propone la unión de cola de milano, ya que presta una fijación más segura que no se desacomodará con el movimiento del usuario.

- Las piezas del butaco se entregan sin un pre ensamble ya que, no sus piezas no presentan mucha dificultad para ensamblar.



- Para asegurar el ensamble y facilitar un desensamblado, se propone una unión de clavija entre los ejes y las patas.

Con el pre ensamblado propuesto se logra reducir las 37 piezas que componen la silla y el butaco a 25 piezas. El ensamblado requiere únicamente de dos personas.

make definitive decisions about the shape, materials, and manufacturing from optimization strategies.

These tests did not represent a problem; they were enough to make modifications and start the detailed execution of manufacturing and assembly drawings and technical specifications. The elaboration of more precise drawings allowed the development of a scale test model within manufacturing limitations, and to adjust protocols for more accurate tests.

Shortly before starting projectual action six, the socialization of the products and results of the project was recorded in a timeline of the construction of a 1:3 physical model (see image 6) to bring closer the production line. The partial 1:1 pieces model some teams could build was also reported. With this material, commensurate charges tests, preventive, and corrective maintenance analysis FMEA[33] (Failure mode effects analysis) were performed, in anticipation of some of the product's life cycle phases to change its detail design. After that, an environmental sustainability validation was carried out by an eco-audit[34]. Since the carbon footprint measurement is only significant if it's used with other reference models, the available in the core were compared. Significant variables were focused on, such as the impact of the raw materials selection and local processes, and transportation. Rather than provide certainties, this test allowed students to identify controllable variables, support environmental sustainability and recognize its importance for professional practice (see image 7).

The chosen channel, costs, and estimated price, cost-benefit ratio were assessed. The validation of the procurement and distribution channel was performed through comparison of the product against others on offer and consumption surveys. Through approximation of

[33] The analysis was based on Sangüesa, Mateo and Ilzarbe (2006. P.148-149).

[34] The licensed software by the UPB and accessible remotely was used.

Image 6

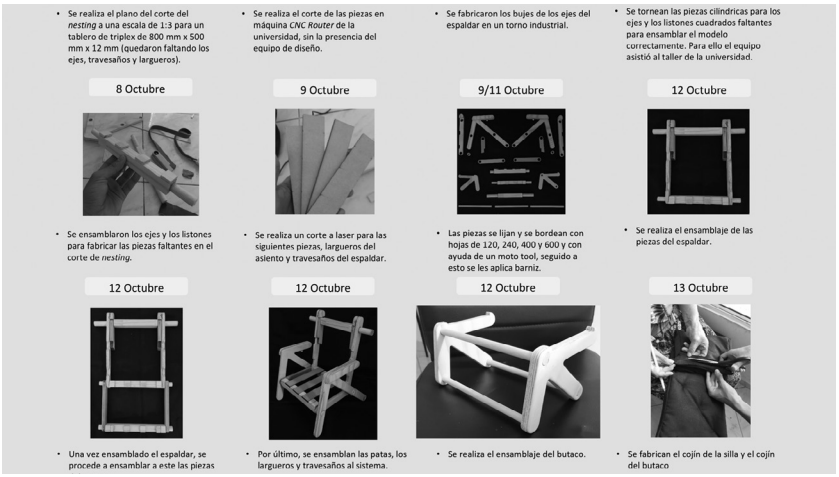
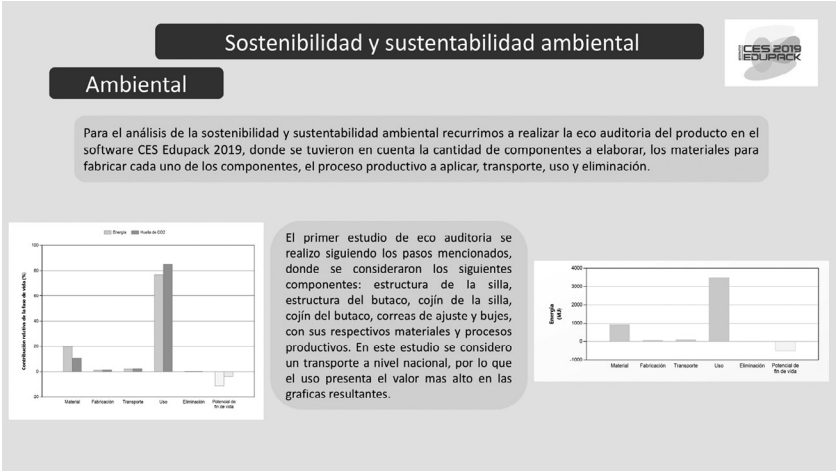


Image 7



costs by materials valuation, processes, and commercial parts. And through, escalated projections of prices based on costs and reference products offered in channels. The findings are no different in scope from those got in the classroom.

Simultaneously, analytical matrices were developed to assess characteristics that provide novelty and product variants. The first considered variables such as appearance, use or function, material, dimensions, weight, duration, productive process, sustainability, and price variables. The second one included variation to replicate the product in other contexts of use, socioeconomic or sociodemographic. We identified characteristics to adjust to some of them (see image 8).

The argumentation of social sustainability gathered validations findings from all dimensions. The analysis and test findings were compared against the existing rules, responsible resource management, certified raw materials, productive capacity, local manufacturing process, and fair-trade practices. Likewise, product coherence with the people's life habits and their perception (user-friendliness, harmony with its context,

Image 8

affective association) was validated using contrast matrix[35], structured interviews and surveys together with photorealistic representations or photomontages in actual situations. Given the qualitative nature of this data, the core components accompanied its interpretation and decision-making according to their scope.

As expected, the product validation in a context with real actors was not possible and validating some functional-operational and aesthetic-communicative requisitions was complex. The usability, functionality, and even the potential usefulness of the product could only be guessed. The findings supposed the object's potential behavior, reducing the got scope during classroom education. Despite the usefulness, that was to perform simulations of the sequences of use, assembly, and operation (from digital models and animations compared with the reference mechanism or objects) and perception tests from photomontages.

Finally during the projectual action six, socialization of the products and findings of the project, an online presentation was held and the final verification, the informe de proyecto (project inform) was presented. It included as optimization prospects the findings of the ultimate validations that could not be deployed as immediate modifications but should be considered in the future. This action was simultaneously academic validations of the students' skills.

Conclusions

Adjusting the core activities to the conditions of virtual mediation implied, methodologically, optimizing methods and tools that had shown effectiveness to cooperatively develop project activities using virtual

[35] An example of these matrices can be seen in Rodríguez-Parada, Romero and Domínguez (2016. p. 3).

images of objects. To achieve this an educational environment was set up using the platforms and applications that allow collaborative work. As shown, this allowed and, finally, specified products validation through simulations and data comparison. The requisitions that allowed to be validated through this method and proving reliability were the techno-productive, economic-administrative, and even historical-political dimensions. The functional-operational and aesthetic-communicative ones that required simulacrum showed little reliability. Although the simulations mitigated (not replaced) this failure, the results were inconclusive. Despite some requisitions being not more critical than others, the uncertainty about some aspects can cause, as Markus says, "catastrophic failures." The experience proved that validating products using one representation form or another, with a certain level of detail, does not impact its validity but its reliability and scope. The more characteristics present, the more reliable findings. Therefore, making a proper interpretation will mean considering both the tools and means used, such as accuracy and the extent of the tests.

The obstacles to develop a prototypical model: the impossibility of performing collaborative on-site work as well as the restricted resources, raised a question about the educational integrality. When it was considered that one member of each team should build and validate it, overcoming resources, it was questioned that when team members are in different locations, cannot meet or there are restrictions to do so. The question is if it is legitimate, from a formative point of view, that performing separate tasks compromises a disparate scope of competence for each other?

To summarize, although the educational experiences of the designers through an online environment opened new perspectives for the projectual processes. It also showed the impossibility to perform under the circumstances described, critical validation activities that affected the level of competence achieved by students in the classroom education and declared by the UPB IDES program.

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Universidad Pontificia Bolivariana	**SU OPINIÓN**	

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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.