Proceedings of the
GREEN Festival 2021

ESADA Design Press

Maquetación y cubierta por Alejandro Pérez Garijo

ISBN: 978-84-120628-5-4
Depósito Legal: GR-1024-2022

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GREEN 2021: AN INTRODUCTION

CONTEXT

It is common now to hear or read people comment that the problems we face today, such as climate change, biodiversity loss, and increasing water scarcity, are not simple to solve. Rather, these are networked, complex problems spanning not one but multiple systems. Even the problems overlap each other, and solutions will need to address a wide range of systems challenges. The systems range from global economic models to how products are designed to how we behave as individuals.

With this understanding in mind, the organizers of GREEN 2021 knew the people at the event, the ideas shared, and the very format of the conference had to be diverse. GREEN 2021 had to combine science, design, art, indigenous wisdom, ethics, products, educational approaches, and local collaborations. Each of these are essential components of the solutions that are needed.

A BRIEF DISCUSSION ON THE SYSTEMS

As articulated in Kate Raworth's seminal book Doughnut Economics, the systems that must be addressed aren't simply how money is exchanged or even who is involved. To honestly address climate change, biodiversity loss, and increasing water scarcity societies must address: what is prioritized, what is valued and what is now, what is lauded and what is scorned, which participants are included in these systems, how the chain of responsibility is viewed in terms of products, packaging, and waste.

With such fundamental questions to be asked or maybe re-asked, societies must redesign a host of systems.

- Education must incorporate these new priorities and perspectives. It must also drive creative and systems thinking.
- Product design must be circular and regenerative by design, consider full life-cycle impacts, and tackled at a system level. Packaging, transportation, use, and ownership must all be re-thought and taught anew.
- Materials used not only in consumer products, but also in construction and architecture must move away from being dependent on extractives such as petroleum and mined metals, and become an active part of the systems design, contributing to ecosystem services such as water and air filtration.
- The underlying chemistry that supports much of modernity must embrace life-friendly, green chemistry. Rather than liberally using chemical compounds that are deleterious to life and create non-biodegradable materials, chemistry must work within life-friendly boundaries and learn to be more eloquent in its formulations.
- Governments, funding bodies, and companies must abandon short-term gain thinking and adopt long-term, equitable, and systems-based models. This will include diverting funding from traditional projects and toward ones that will manifest the new reality that is required.

GREEN 2021 MINDSET

This context is important for the reader to consider. Unlike a more traditional conference proceeding, t his collection shares diverse perspectives using diverse narrative styles. This is critical for properly conveying the tone of GREEN 2021 and for doing each submission justice. The reader is encouraged to keep this wider context in mind while reading the articles. The authors

explore these challenges and systems from different perspectives. Sometimes a perspective will be one the reader is unfamiliar with or approaching these systems from a more limited, locally achievable scope.

The collection does nest each submission into one of three general themes: Urban-Nature Connection, Circular Design, and Society and Nature. Each submission has elements of all three themes as would be expected given the networked, complex context. For ease of the reader though, this collection has focused on the central message of each submission and aligned them accordingly.

URBAN-NATURE CONNECTION

One myth GREEN 2021 sought to dispel was the pervasive disconnect between urban environs and nature. For many, nature is something one must travel to experience. It is a forest in the Sierra Nevada, a coral reef in Australia, a glacier in Iceland, and so on. However, whether that is a local park, the moss growing on the side of building, or the ant colony discovered on the sidewalk, we are surrounded by nature even in our urban centers. This false division not only separates us from nature physically, it separates us conceptually and practically. It has led urban design to neglect nature and designers to not even consider the possibility that a building, a street, or entire city might function as part of the wider ecosystem it sits in.

Activities during GREEN 2021 and subsequent submissions here, are focused on developing and implementing sustainable cities and connecting to nature in our urban backyards. They span architecture, territorial distribution, energy efficiency, ecosystem services, and more.

CIRCULAR DESIGN

Instead of employing degenerative linear design, a regenerative future will require designing for circularity. Companies, countries, and individuals need to shift their understanding from a consumptive mindset where take-make-consume-waste is the standard model to a circular mindset where products, cities, and services are designed to be re-used, repaired, re-purposed, and recycled. This includes employing life-friendly, green chemistry that employs non-toxic production processes and cycles raw materials verses requiring vast quantities of freshly extracted virgin materials.

GREEN 2021 explored ideas regarding narrowing, slowing, and closing loops in human design, with nature as a mentor and inspiration. This included ideas and projects in agriculture, fashion, and the built environment.

SOCIETY AND NATURE

There is a growing recognition worldwide regarding the need to reconnect and rediscover the natural world. It can be seen in a recent surge of scientific papers and books discussing everything from the Asian-Pacific practice of forest bathing to the quantifiable effects of exposure to nature and human health to increased awareness of indigenous knowledge and connection to nature. It is even being rediscovered in the realm of climate change where Nature-based Solutions are gaining significant attention.

Drawing society back to nature, to learn from nature requires a range of interventions into the complex systems that make up society. During GREEN 2021 Society and Nature activities delved into indigenous wisdom, communication, art, and even how societies align their public and private funding.

II (INTER)NATIONAL BIOMIMICRY WEEKEND
Esadapress editorial
Granada, 5-7 November, 2021

THE GAPS AND POTENTIAL OF ECOSYSTEM SERVICES IN BUILDINGS AND URBAN ENVIRONMENTS

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Keywords: Ecosystem services 1; Built environment 2; Interdisciplinary interaction 3; Ecological literacy 4

Abstract. *Ecosystem services represent a high potential for designing regenerative and ecologically functional cities and buildings. By imitating ecological functioning in urban environments, ecosystem services can be generated in and on buildings, in parks and streets. Translating and implementing ecological processes to the built environment requires ecological literacy and practical proof of innovative concepts. Several ecosystem services designs already exist and can be taken as proof of concept to reduce risk-taking among building professionals and decision makers. However, more knowledge is required regarding the benefits that ecosystem services designs deliver quantitatively as well as qualitatively. Therefore, interdisciplinary research and collaboration between scientists and industrial professionals needs to be reinforced and cultivated also among students. In a related activity, design and science students collaborated on ecosystem services generating design briefs for cities mimicking or working with ecological process to achieve functionality of the product. Future collaborations, knowledge exchange and interdisciplinary interactions can be predicted between the activity participants.*

1. INTRODUCTION: OBJECTIVES OF THE PAPER AND METHODOLOGY

This paper introduces the increasingly relevant topic of ecosystem services in the urban and built environment. Two activities to that end have been facilitated during the GREEN conference 2021. Each indicated section below represents an individual activity. Each activity is described by introducing the societal and scientific relevance of the topic and the key outcomes of the activity. The ‘Ecosystem Services: Understanding the processes in natural systems’ activity was facilitated in the form of a presentation with a Q&A afterwards. The ‘Ecosystem Services Challenge’ was a four-week pre-conference activity with a poster exhibition during the conference. This activity involved the coordination between the educational institutions of ESADA (Escuela Superior de Arte y Diseño de Andalucía) (activity coordinators: Dr. José Antonio González, Pedro Martínez, and Marina Quesada) and Utrecht University (activity coordinators: Dr. Jaco Appelman and Katharina Hecht).

2. 'ECOSYSTEM SERVICES: UNDERSTANDING THE PROCESSES IN NATURAL SYSTEMS'

Ecology and eco-literacy mean 'knowledge of home'. The Earth is our home and as humans we share this planet with many other species (Kumar, 2019). Economy means 'management of home'. In order to survive in a world with a stagnated economy, governments as well as individuals have to better understand ecological systems and reform the idea of linear economy towards a circular system that is resilient to external and internal change.

More than 60 percent of our human population lives in cities and this trend is increasing. By providing shelter and security, buildings cover a basic human need (Kenrick et al., 2010). In biological terms, buildings have become our habitat (Blanco et al., 2021; Rutledge et al., 2011). However, the resources that a city provides to humans are largely not generated in the city itself but originate from non-urban biological ecosystems (Derrible et al., 2021; Ulgiati & Zucaro, 2019). Buildings are among the largest consumers of raw and bulk materials on Earth (Metabolic, 2020). Building construction uses 40 % of the material that enters the global economy (Khasreen et al., 2009; Ruiz Gutiérrez, 2015). This makes buildings an urgent target for regenerative development.

The predominantly used economic model of 'take-make-consume-dispose' assumes that natural resources are abundant and always available (European Environment Agency, 2020). However, these traditional consumption patterns have led to resource overuse and depletion which increasingly results into higher material prices and degraded or polluted ecosystems (Ellen McArthur Foundation, 2013; Jørgensen et al., 2018). Circular material flows in all life cycle stages of buildings are suggested alternatives to compensate for diminishing raw material sources (Masi et al., 2017; Ngwepe & Aigbavboa, n.d.). Despite increasing efforts to re-use, recycling, and repair, Deetman et al. found that material demand for building construction will overtop material outflow from scrap materials in most parts of the world until 2050 (Deetman et al., 2020; Masi, Day and Godsell, 2017). Several sustainable strategies, technologies, and designs have been developed over the past decades that allow a reduction of the "damage caused by excessive resource use" however are mostly not regenerative or net-positive (Birkeland, 2020a; Reed, 2007).

Ecosystem disturbance and depletion can only be mitigated and reverted when designing for urban environments that function like undisturbed biological ecosystems that provide all life-supporting resources (Birkeland, 2020b; Pedersen Zari, 2018).

The presented speech aimed at explaining the high potential of ecosystem services integration to achieve ecologically functional building designs. Existing examples of ecosystem services generating building designs delivered proof of concept to the audience that this approach is practically feasible. The 'strategies for designing urban ecosystem services' diagram version 1.0 was presented as inspirational tool for designers to learn about and design for ecosystem services in the built environment (Pedersen Zari & Hecht, 2020).

Biological ecosystems are providers of ecosystem services which are the 'the benefits that people obtain from ecosystems' (Alcamo et al., 2003; Mader et al., 2011). The Millennium Ecosystem Assessment and the UK National Ecosystem Assessment categorized ecosystem services into four different groups (Alcamo et al., 2003; UK National Ecosystem Assessment, 2012). Provisioning services are the material benefits that humans obtain from ecosystems such as food, fresh water, and energy. Regulating services derive from the regulating processes of ecosystems like climate regulation or pollination, while supporting services are the underlying processes that are essential for the generation of all other ecosystem services. Examples are soil building and nutrient cycling. The fourth group are the cultural services which are the material benefits that humans derive from ecosystems such as recreation, education or aesthetic inspiration (Pedersen Zari & Hecht, 2020; UK National Ecosystem Assessment, 2012) (figure 1).

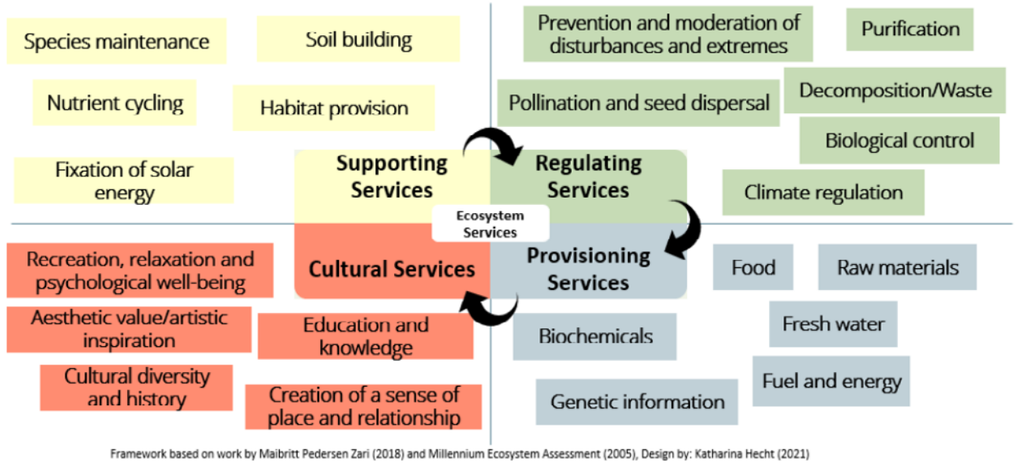

Figure 1: Ecosystem services groups and respective categories according to the framework developed by the Millennium Ecosystem Assessment (2005) and Maibritt Pedersen Zari (2018) for the built environment. Arrows indicate how ecosystem services groups are building on each other. Design by: Katharina Hecht (2021).

Designing for ecosystem services in the urban built environment can improve or protect the integrity of systems in the biosphere, thereby supporting for example the provisioning of habitat, energy, water, and biodiversity.

As many biological ecosystems have been polluted and damaged in their functioning, the generation of ecosystem services will continuously reduce (Peng et al., 2017).

Existing buildings ask for refurbishment and reintegration into the local ecosystem through implemented regenerative designs. New building projects have the opportunity to design with nature from scratch which can result in a more efficient re-embedding of buildings into biological ecosystems. However, a better understanding and management of biodiversity and the complexity-stability relationship in ecosystems is needed, especially for the built environment (Landi et al., 2018). Models are required that can explain and predict evolving biotic and abiotic interactions between species that inhabit ecosystem services generating buildings. More research is required that explains 'the mechanisms of how ecosystems provide services' (Pedersen Zari, 2017). Furthermore, indicators and benchmarks need to be defined to 'measure the capacity of ecosystems to provide services' and metrics to measure ecosystem services, especially in and on buildings (Pedersen Zari et al., 2020).

As designers, architects, and building developers often think visually and spatially (Bertel, 2005; Pedersen Zari, 2018), they are also able to understand temporal and three-dimensional relationships that generally exist in nature (Pedersen Zari, 2018). The focus should be on biological relationships, however, their interconnectedness with social relationships also needs to be considered. Implementing ecosystem services designs in buildings on a larger scale can contribute to the creation of buildings that are adaptable to the changing climate, and that at the same time mitigate building-related climate change (Pedersen Zari, 2018).

Due to the globalization of pollution and the production and consumption network, the whole world requires and seeks solutions for more sustainable buildings. The solution finding is a global and interdisciplinary effort and leveraging from solutions of other places than our immediate surrounding can be very efficient.

In the international and interdisciplinary context of the GREEN conference 2021 context, this speech raised interest among designers and policy makers mainly from Spain and the Netherlands to start working with the concept of ecosystem services to develop ecologically functional, instead of green-washed products and policies.

More research and practical implementation of ecosystem services in buildings is urgent because possibilities to substitute or at least reduce traditional building designs and materials need to be to further developed, tested and implemented in buildings (Nußholz et al., 2019; Vallas & Courard, 2017; Vishwakarma & Ramachandran, 2018). Therefore, collaborations between architects, designers, policy makers, engineers and biologists or ecologists are necessary and need to be reinforced.

3. 'ECOSYSTEM SERVICES CHALLENGE'

The challenge of modifying currently predominant paradigms and worldviews towards regeneration persists across cultures and countries. Human activity and consumption have not only led to accelerated climate change and environmental degradation, but also to increased human health issues, social injustice in our global production network, and economic recession (Lombardini, 2020; van Benthem et al., 2020).

'Designers should be seen as initiators of a process and not molders of an object' (TLmagazine, 2020). The goal hereby is to transition people's understanding of elements in the anthropogenic system such as buildings, materials, and products from simple static and dead units towards complex, variable, and living modules. Design processes have been identified to be ecological processes (Pedersen Zari et al., 2020). Therefore, ecology should become an essential component and a leading force in decision making and design processes (Pedersen Zari et al., 2020). Integrating ecologists and biologists can be an asset in this development. The bridge from mere theory and technological and scientific developments to the real world and industrial practice requires to be reinforced and further developed.

Interdisciplinary collaboration has to be cultivated early on during education to prepare students to efficiently solve real-world challenges in their future professional career (Wang et al., 2020). A first collaboration has been set between biological science and design students in the Netherlands and Spain. Product design students developed ecosystem services generating designs with a special focus on solving challenges in the city of Granada. Therefore, they consulted science students from Utrecht University as experts to explain and suggest ecological functions, processes, and designs to mimic and implement into the innovated product. Resulting designs focused on ecosystem services generation from all groups such as increased biodiversity, food production, water purification, energy generation through bacteria and 'pressure generated by the people walking on [the stairs] or seismic movements in active localities (figure 2).

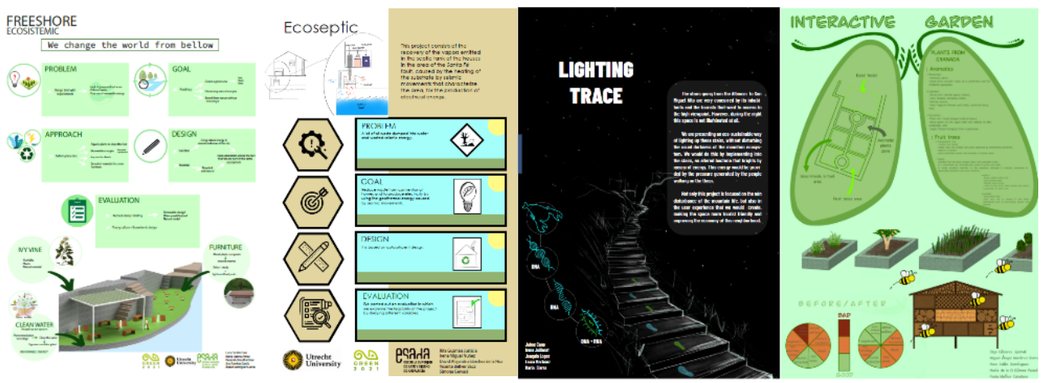

Figure 2: Posters representing the ecosystem services generating designs developed by the product design students of ESADA in Granada, Spain in consultation with bio-inspired innovation science students from Utrecht University in Utrecht, Netherlands (2021).

4. CONCLUSIONS

The concept of ecosystem services offers a possibility to design for ecologically functional products, buildings, and urban environments. The conference presentation about the topic raised importance to tackle sustainability challenges by generating ecosystem services in and on buildings and cities. Attention was drawn towards existing and innovative building and urban designs but also to the lack of practical experience and the quantification of ecosystem services designs in buildings. A call was made to collaborate between different disciplines to achieve a feasible and effective integration of ecosystem services designs into the urban and building planning and construction process.

The ecosystem services challenge resulted in collaborative solution finding between design and bio inspired innovation students. Scientific knowledge was exchanged and innovative and ecologically functional designs were developed for the urban context. Cultural and language barriers had to be overcome for an effective teamwork. This activity can be seen as a first experience for young professionals to collaboratively create solutions that serve not only the economy and people but also the biological environment by generating ecosystem services. The challenge was intended as the initiator exercise for future collaboration between students and organizations to further develop first ideas and drafts into marketable products or designs with the goal to support the transformation into sustainable cities.

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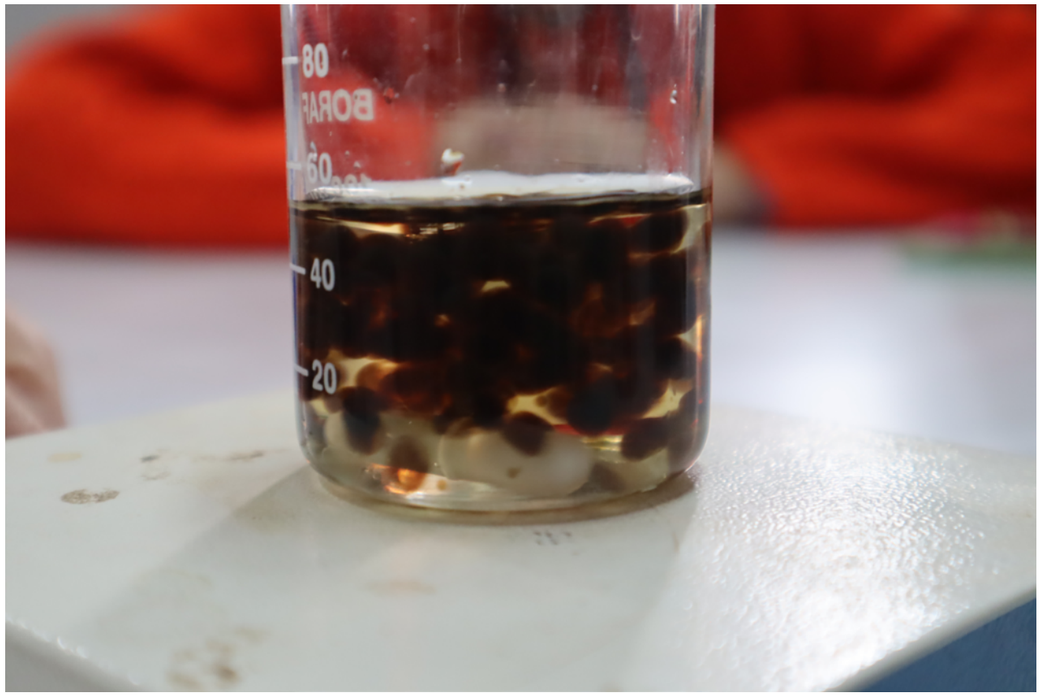

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Esadapress editorial
Granada, 5-7 November, 2021

THE WONDERFUL WORLD OF BEES AND THEIR TEACHINGS

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Keywords: Honeybees 1; Bio inspired design 2; Ecosystem services 3; Urban context

Abstract. *Bio inspired design and biomimicry are increasingly gaining the attention from urban planners and architects. Both methods are offering solutions to sustainability and circularity. The structure and functioning of biological systems such as a honeybee colony can teach us a lot about efficient and biodegradable building design and non-verbal communication techniques. By translating this knowledge to the building and urban context we discover which ecosystem services can be generated by applying characteristics of the honeybee lifestyle in the manmade environment. In an exemplary activity, scientific knowledge about honeybees served as a basis for translational idea creation to solve urban challenges and to design for more efficient buildings. Enthusiasm about ecological systems and honeybees could be observed among the students and activity participants.*

1. INTRODUCTION: OBJECTIVES OF THE PAPER AND METHODOLOGY

In order to design buildings and cities as living units and complex evolving systems, existing and evolving relationships between and within these units need to be better understood (Landi et al., 2018). Most of these relationships are of ecological nature. Natural systems present time-tested models that are characterized by resilience through multi-modularity, self-organization, adaptability and multi-functionality (Benyus, 2002). This mindset (why we design) and behavioral (how we design) shift is a process that requires the fusion of a multitude of different approaches to reach a large target group of professionals. Environmental education and bio-inspired innovations are already flourishing fields with a great impact on many people from different cultural and professional backgrounds (Biomimicry 3.8, 2016; International Living Future Institute, 2021).

During the GREEN 2021 conference, the presented honeybee-based activity consisted of: a) A presentation on social structure, communication, and the ecosystem services they provide. b) An interactive game where the participants imagined what our world would be like inspired by these insects. Both parts are detailed below.

2. PRESENTATION ABOUT HONEYBEES

Honeybees are great examples for biomimicry on an organisms, behavior, and ecosystems level. Specifically, the species Apis mellifera (common name: European honeybee) is characterized by its highly social behavior called eusociality where there is a division of labor between adult individuals,

cooperation in brood care, and overlapping generations. These eusocial bees live in highly populated colonies in honeycombs made up of hexagonal cells built by the workers from the wax produced by their brain glands. The cells have several uses, such as the rearing of larvae and the storage of reserves such as pollen and nectar (Straub et al., 2015). The social structure of honeybees is made up of three different castes or individuals that are the queen, workers, and drones (Figure 1). Each of these individuals performs different functions and are essential for the proper functioning of the colony.

Figure 1. Castes of Honeybee colony: Queen, Worker, and Drone, respectively.

Honeybees are highly sophisticated insects that have coevolved with flowering plants for millions of years, generating a complex interdependence (Bradbear, 2009). Pollination is the most important role played by honeybees as they represent more than 90 per cent of the world's 107 major crops (Klein et al., 2007), contributing to the agricultural decline of approximately 35 per cent of world food production (Smith et al, 2015), thereby providing a dynamic in both wild and agricultural ecosystems, preserving biodiversity and helping to ensure food security for the world's population (Ortiz-Sánchez et al, 2018). Apis mellifera bees are among the most important pollinators because of their high floral specificity and their processing efficiency; since in a single trip a bee can visit between 50 and 1000 flowers of a single plant species at a time, which takes between 30 minutes and four hours (Urbanowicz et al.,2020).

Communication is the key to social life and Apis mellifera bees have a high capacity to communicate with other bees in the colony, for example through the language of dance to indicate the location of the food source, making the process more efficient. Likewise, the chemical communication that is carried out through the different pheromones produced by the queen, the larvae, the workers, and the drones are essential for the correct functioning of the colony and its survival (Bortolotti and Costa, 2014).

Regarding the structure of the honeycomb and the materials used for its construction, the honeybees use biodegradable and multifunctional materials. The construction worker bees are responsible for producing the wax from their wax glands, which are the basis for the construction of the cells, also using other materials such as propolis and resins that are collected from the environment and used to cover the cracks, holes, spaces and glue the moving parts of the hive. Likewise, honeybees use propolis to embalm foreign bodies that they cannot expel from the hive. Due to its antimicrobial properties, propolis is used to seal the brood cells and for bactericidal and antiseptic protection of the hive (Bankova et al., 2018). Regarding the design of the honeycombs, the honeybees build their cells with precise 120-degree angles that form perfect hexagons, allowing the least amount of wax and space to be used. This makes the structure light and stable.

Honeybees provide us with different ecosystem services that are related to each other, providing mutual and interrelated benefits between society and ecosystems. Specifically, bees provide us with:

- Supporting services that are key to the balance and functioning of ecosystems such as pollination and the maintenance of biodiversity, as well as forest conservation and forest restoration.

- Provisioning services such as food, raw materials and natural resources that are obtained from the variety of products that honeybees offer us, such as honey, pollen, royal jelly, wax, living material, propolis and apitoxin, which are used in human nutrition, in the manufacture of therapeutic products, and in the beekeeping industry.
- Regulating services such as pollination and pollution bioindicators. Honeybees are quickly becoming key bioindicators due to their cosmopolitan distribution, the frequency of their flights, and the large areas they cover in search of food, being exposed to multiple contaminants that are retained in their body hairs, enhancing the accumulation of these substances, increasing analytical sensitivity, and allowing the study of environmental contamination (Gutiérrez et al., 2020; Haiyan et al., 2020).
- Cultural services since honeybees are an inspiration for art, music, literature, traditions, education, and technology. In addition, new associations and foundations are created around the world around bees that favor the exchange of knowledge, interdisciplinarity and the reduction of inequalities between countries, pointing towards sustainable development (Patel et al., 2021).

3. INTERACTIVE ACTIVITY

An efficient educational method to teach about biological facts are games (Naik, 2021). Especially translational learning and research can be done using practical methods such as interactive games. In order to practically translate and apply the previously presented characteristics of honeybees, an interactive game was played that asked the audience to brainstorm about how honeybee traits and behaviors might be translated into societal solutions for the urban and built environment. Therefore, honeycomb-shaped cards were designed with facts about honeybees that could be translated to societal solutions for cities and buildings on the back side (figure 2). Examples for honeybee facts were 'a honeybee collects natural resources from different places in the environment' or 'the beehive is built with hexagonal cells that result in a stable, adaptable structure and optimized space'. Answers for honeybee fact translation to urban solutions were for example, to make the most of building materials or to implement natural resources such as propolis which is a multifunctional material used by bees for constructing the honeycomb walls and keeping them hygienic. As for the design of the combs, this could be applied to the design of storage cabinets to save space, among others. With regard to the storage of resources by bees for times of scarcity, this could be applied to self-sufficient buildings where resources are generated and stored to be used in uncertain times. The different spaces in the buildings could also be used to plant and cultivate a variety of vegetation, making the most of the space and its conditions. Finally, the participants mentioned one of the future challenges the society will face. Latter is related to the type and amount of waste that is generated every day. Following the example of honeybees, the great challenge for humans will be to convert our waste into biodegradable waste and reduce the quantity of existing waste.

Figure 2. Honeybee game composed of 12 honeycomb-shaped individual cards with each a fact about honeybees that can be bio mimicked in cities or buildings

4. CONCLUSIONS

Through the activities proposed in relation to honeybees, the participants were able to learn about the work carried out by these valuable insects and how they relate to their natural environment in a sustainable manner. Based on this knowledge, the participants created ideas applicable to the design and construction of buildings that integrate ecosystem services and use multifunctional and biodegradable materials with the purpose of building a more sustainable and friendly society with the conservation of the environment. These activities highlighted the importance of creating spaces that lead to a better understanding of the multiple and complex relationships existing in nature that allow the balance and self-maintenance of ecosystems. In these spaces discussions and reflections on the current problems of society are encouraged as well as finding solutions to create bio-inspired solutions that have the potential to solve sustainability related challenges locally.

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II (INTER)NATIONAL BIOMIMICRY WEEKEND
Esadapress editorial
Granada, 5-7 November, 2021

GREFA: GENERANDO BIODIVERSIDAD EN EL MEDIO NATURAL Y URBANO

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Keywords: biodiversidad, Fauna auxiliar, agrario, urbano

Abstract: *La convivencia de agricultura, ganadería y los asentamientos humanos con el medio natural, se sustenta en una relación de decenas de miles de años de antigüedad. Ésta se ve cada día más amenazada por la fuerza de los intereses económicos de un modelo de desarrollo basado en el crecimiento desenfrenado, además de por la ineptitud humana que centra su mirada en actitudes herméticas y cortoplacistas.*

Todo esto da como resultado un panorama desolador para la conservación de nuestros asentamientos y de los ecosistemas agrarios en los que habitan millones de personas y en los cuales desde hace décadas no paran de desaparecer especies de flora y fauna como consecuencia de una gestión antropocentrista con tintes autodestructivos. Es urgente prestar atención a los mensajes que lanza la naturaleza en forma de extinciones locales de especies y aparición de nuevas plagas y enfermedades en los medios donde se produce el sustento que alimenta al mundo y se cobija nuestra especie.

Por eso desde GREFA no se ha parado de trabajar en la recuperación de especies y hábitats en convivencia con el medio que habitamos así como con las actividades agropecuarias y con los productores conscientes de la grave sobrexplotación a la que se está sometiendo nuestro planeta.

1. INTRODUCCIÓN

Uno de los mayores problemas que se está generando para la conservación de muchas especies, es la desvinculación del ser humano con su entorno vital. Desde hace décadas, nuestros hábitos, costumbres, medios de producción y de construcción, están generando espacios de exclusividad para el uso y disfrute de nuestra especie. Esto constituye un craso error, pues la convivencia e interacciones entre unos y otros seres vivos resultan vitales para el correcto funcionamiento de cualquier ecosistema y el desarrollo equilibrado de sus diferentes ciclos biológicos. La continua extracción de elementos de un ecosistema y la reducción de la biodiversidad en el mismo, hace más vulnerables a las especies residentes frente a enfermedades, plagas o extinciones. El caso de los asentamientos humanos en forma de pueblos o ciudades asépticos son el mejor ejemplo a estudiar.

1.1. Contexto en el medio agrario

Como se viene advirtiendo por la comunidad científica internacional y los grupos ecologistas que trabajamos en los medios agrarios, desde hace varias décadas se está experimentando un grave proceso de regresión de las poblaciones de numerosas especies vinculadas a los agrosistemas.

Este viene por muchas razones, principalmente el uso intensivo de fitoquímicos, pero también por la destrucción del hábitat. Algo que no es más que un aviso de las graves consecuencias que se pueden desencadenar para la salud pública.

La creciente industrialización del campo y el crecimiento dimensional de la maquinaria agraria y sus aperos imponen las re-concentraciones parcelarias y con ello la destrucción de linderos, bosquetes, arroyos y matorrales aislados que dan cobijo, alimento y paso a numerosas especies históricamente aliadas de la agricultura.

De una forma alarmante, se ha aceptado socialmente entre muchos profesionales del sector el concepto de “un campo limpio”, como un terreno dominado por la especie cultivada y perimetrado por lindes, cunetas y arroyos quemados por el uso de herbicida. Un uso de herbicida que tiende a eliminar las complejas composiciones vegetales que se desarrollan en estos espacios lineales circundantes, permitiendo exclusivamente el rebrote de aquellas especies más invasivas y que precisamente quieren ser combatidas como competidoras del cultivo (Bromus, avena loca, ballico, cola de zorra... todos ellos también conocidos como espigajos).

Sin duda este vergonzoso fenómeno puede ser observado por cualquier persona independientemente de su formación o conocimientos en agricultura o botánica. Basta con observar aquellas parcelas donde en el invierno ilícitamente se trata de herbicida la cuneta del camino o el arroyo adyacente viéndose una posterior colonización de pocas especies de gramíneas en la sucesiva primavera. En el caso de las esquinas, donde la maniobrabilidad del tractor es más complicada, no suele llegar el tratamiento de herbicida, observándose ricas y complejas composiciones florales que atraen gran cantidad de polinizadores, muy valiosos para el correcto desarrollo vital del cultivo. No se debe olvidar que esta gran diversidad floral aumenta la competencia por el espacio y limita el desarrollo de aquellas plantas invasivas ya mencionadas.

Ni que decir tiene, que este abuso de fitosanitarios en el exterior de las parcelas cultivadas (linderos, caminos, arroyos, drenajes, perdidos etc.) acarrea graves consecuencias por filtraciones a los acuíferos y aguas superficiales y también resulta perjudicial para el ganado de diente que ingiera el veneno rociado en el pasto pudiendo llegar a provocar envenenamientos y abortos en el caso de las cabezas preñadas. Un gravísimo problema para la ganadería del cual misteriosamente se hacen poco eco los medios de comunicación.

1.2. Contexto de los núcleos urbanos

En pleno siglo XXI y en tan desarrollado mundo occidentral, siguen siendo necesarias de emprender campañas divulgativas para fomentar la conservación de varias especies que aún a día de hoy se enfrentan a la vergonzosa amenaza de la persecución directa por parte de algunos humanos.

Resulta además, que todas estas especies están protegidas por ley entre otras razones por su valiosa función ecológica como controladores de poblaciones de insectos y roedores.

Algunas de las más habituales y más amenazadas son golondrinas, vencejos, aviones, sapos, ranas, tritones y serpientes. Todos ellos animales muy vinculados a los entornos urbanos y rurales-donde tratan de cohabitar utilizando casas, jardines, huertos y pilones como refugio para desarrollar su ciclo biológico. Éstos pequeños aliados facilitan la supervivencia de nuestra especie indirectamente alimentándose de aquellos otros seres que en abundancia demográfica pueden comprometer la salubridad de las personas y sus actividades productivas: por ejemplo ratas, ratones, mosquitos, caracoles, moscardones, etc.

Pero lamentablemente todavía es habitual dar con desaprensivos que dan muerte a estas indefensas criaturas o les hacen la vida imposible destruyendo sus refugios o interfiriendo (en ocasiones también sin mala fe) en sus ciclos reproductivos.

Por ello es preciso el esfuerzo de organizaciones como GREFA en las que se trabaja entre otras cosas en recordar que el bien común y el interés general que engloba la salud de los ecosistemas y por tanto de las personas; debe prevalecer siempre por encima de los intereses particulares, egocén-

tricos y cortoplacistas que ponen en jaque la supervivencia de la fauna auxiliar y contribuyen a los desequilibrios ecológicos mediante sus conductas incívicas.

2. MATERIAL Y MÉTODO

Desde 1981, GREFA ha tratado de combatir las agresiones sobre las especies y los espacios con numerosas líneas de trabajo como la cría en cautividad de especies amenazadas, programas de reintroducción y reforzamiento, investigación, conservación, seguimiento y estudio de fauna, atención veterinaria, sensibilización, educación ambiental, reforestación, construcción e instalación de nidales y otro tipo de refugios, transferencia a la administración y cooperación con otras entidades y sectores.

3. CONCLUSIONES

Es necesario seguir trabajando en la divulgación científico-técnica y la educación ambiental, de forma paralela a la implementación de medidas correctoras y preventivas que ayuden a frenar la regresión de tantas especies beneficiosas e imprescindibles. Pese a todos los esfuerzos que se puedan realizar desde ONGs, otros colectivos, instituciones científicas o particulares resulta imprescindible una legislación más rigurosa y una voluntad humana por cambiar y exigir cambios.

II (INTER)NATIONAL BIOMIMICRY WEEKEND
Esadapress editorial
Granada, 5-7 November, 2021

BIOMIMICRY TOURS

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Keywords: education, biomimicry, observation

Abstract. *"Biomimicry tours" are presented as a creative way of teaching biomimicry in an urban environment. They are based on the idea that all organisms can teach us something about the context in which they originated – even if we observe them 1000s of kilometres away from that place. The tours consist of a short itinerary around a park, district or city with several planned stops for discussing living beings and systems. Small games, challenges and other activities at each stop are tailored to the specific tour group. The overarching theme of discussions and activities falls into biomimicry learning. Tour-goers should come away with a grasp on how nature designs for function and with a new appreciation for the delicate intricacies of even the most seemingly simple organisms.*

We begin this paper by describing our objectives in designing these tours, and their intended use within the ecosystem of methods for teaching biomimicry. We talk about some of the considerations that went into creating the tours, and then give a detailed description of the first tour prototype. Finally, we recount our experience of running the tour during GREEN 2021 and present key takeaways for further development.

1. BACKGROUND

There are several common settings for learning biomimicry. More and more academic classes are being taught both online and in educational institutions, whether in the context of a broader study program or even as stand-alone certifications. On the other end of the spectrum, intensive biomimicry immersions bring students to abundant remote ecosystems of specially adapted flora and fauna which delight the senses as they inspire new understandings of the workings of our world. Other practices include instructional seminars, hands-on workshops and a host of asynchronous options in the form of books, magazines, pre-recorded videos and more.

Biomimicry tours, in which participants experience a brief immersion in an urban location, are a different way to experience the discipline. The team at Biomimicry Granada has developed tours in the hope of momentarily "transporting" participants to the original home of different species observed and discussed along the way. This is of course no substitute for a full immersion, but we wish to bestow tour-goers with some of the awe of discovering in-situ how local organisms reflect their homes. We look to teach people how to look at all the living things they encounter in their day-to-day through a lens of place and adaptation; that is, through the lens of biomimicry.

2. COLLABORATIVE DEVELOPMENT

The biomimicry tours were developed in collaboration with a group of students the Ethical and Responsible Business Network at UW Madison's School of Business (ERBN). Whereas the team at Biomimicry Granada developed technical and logistical content for the tour, ERBN carried out several adjacent studies.

One of these tasks was marketing analysis based on the User-Personas methodology (Cooper, 1999). Five proxy user groups (a study-abroad student, a business person, a local family, a tourist family and a local teenager) were considered. The analyses on abilities and interests of each user group influenced the development of a single generic tour. In future iterations it would be useful to cater the specific tour experience to different user types.

The second ERBN study consists of a matrix of impact (energy, materials, water, societal impacts, greenhouse gases) flow at different stages, including transportation to and from the tour location. ERBN made reasonable assumptions which they then translated into expected impacts. This matrix is used in two ways. Impacts can be communicated to tour participants in order to convey the effect simple human decisions have on the environment. On the other hand, Biomimicry Granada designed the tour with the goal of maximizing (minimizing) possible positive (negative) impacts called out in the matrix.

3. DESCRIPTION

A biomimicry tour follows a path through the city, with a number (dependent on audience and desired tour length) of stops strategically planned in the vicinity of certain plants or groups of plants. Incorporating animals and fungi as the subject of tour stops is more difficult due to their mobile and/or temporary nature. Nonetheless, several attempts at developing animal and system/level tour stops have been made (see below).

The original tour developed by Biomimicry Granada, which was adapted for the occasion of GREEN 2021, takes place entirely in Fuente Nueva Park, located on Avenida de la Constitución, in the city of Granada, Spain. This version incorporates 6 stops, including an initial “welcome stop”, three plants, one natural system and a stop focusing on nature’s unifying patterns (The Biomimicry Institute, n.d.).

At each stop, tour-goers are asked to close their eyes as a guide describes the natural ecosystem from which the focus-species originated. Then we discuss with participants how the species fits into the context of this place, what are the attributes which allow it to survive, and what functions these attributes perform. This is followed up with an activity directed at further developing knowledge, observation skills or even applying the natural models observed to participants’ lives and/or jobs. Table 1 briefly describes the organism highlighted at each stop, the context and mechanisms discussed and the follow-up activity.

As originally designed the tour did not employ any auxiliary materials for teaching. Through a series of pilots, we discovered that tools, toys and reading/writing materials enhanced the experience for the different persona profiles. Families are especially interested in observing nature with small bug catchers and magnifying glasses. University students appreciate extra literature whereas working professionals enjoy homework to practice applying biomimicry thinking to innovation. For all audiences we developed a series of postcard-like informative documents where they can follow along with the explanations of the different tour stops.

Table 1 Description of tour stops.

Tour stop	Context	Activity
Welcome	We welcome everyone to the tour at the southeastern entrance to the park.	Participants are asked three questions about what grabs their attention at the stop.
Nature’s Unifying Patterns	Introduction to the biomimicry toolkit.	Participants have 5 minutes to find examples of the patterns in the park.
Pomegranate	The ripening process of a pomegranate in the Middle East.	Participants fill in an analogy between the pomegranate and human-made packaging.
Daisy	Efficiency in nature and seed packing on the flower head.	Groups with children are given bug-catchers. Older groups do an activity on the golden ratio.

Tour stop	Context	Activity
American Agave	Hot/dry climate of Mexico and the southern United States.	Exercise for applying cooling strategies from a nearby cactus to manmade buildings.
Soil and worms	Discussion of soil complexity and importance to humans. Ecosystem view of soil.	Wrap-up, questions and farewell.

4. TOUR AT GREEN 2021

Biomimicry Granada offered the previously described biomimicry tour as a lunchtime activity on day 2 (Saturday, November 6th, 2021) of GREEN 2021. Tour expectations had to be adjusted for two reasons. Available time was constrained by the GREEN 2021 program, and the audience was larger than usual at around 30 participants.

The crowd was split into two groups to be taught in Spanish and English respectively. Each group carried out the introductory observation task (see Table 1), and then the Spanish group discussed the pomegranate and daisy, while the English group delved into nature’s unifying patterns (some photographs in Figure 1). We then swapped tour guides and each group carried out the activities that the other group had covered previously. The final two stops were not contemplated for timing reasons.

GREEN 2021 conference-goers were very participative and even took the initiative to lead some parts of the activities. For example, when asked why she thought different trees had such varying leaf geometries, one member of the English group led the others to explore a particularly old specimen and imagine what events it had experienced throughout its life.

Figure 1. The tour group searches for examples of nature’s unifying patterns around the park

Figure 2. Luis tells the story of the life of a pomegranate to the Spanish group.

5. CONCLUSIONS

Biomimicry tours have the potential to offer many of the benefits of a full immersion without the (financial, temporal, environmental) burden of traveling to a remote location. They provide small snippets of evolution and adaptation, and are a great instrument both for introducing newcomers to the biomimicry way of thinking, and reinforcing creative habits among seasoned practitioners.

Feedback was positive. A second planned tour for conference day 3 was cancelled for logistical reasons, with several participants expressing disappointment in not being able to continue the experience. We also received suggestions for improving the tour, and many creative ideas for applying the different natural models in a biomimetic manner.

Further tour development will focus on expanding number of tour stops and locations, as well as further diversifying activities at each stop so as to provide a more tailored experience to each user profile. We imagine in the future that a single itinerary may look very different if offered to an elementary school class with a focus on environmentalism and a product design team looking for innovation inspiration.

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Esadapress editorial
Granada, 5-7 November, 2021

BIOREMEDIATION OF ALPEORUJO BY SAPROB FUNGI AND ITS USE IN AGRICULTURE

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Keywords: Alpeorujo; amended; sustainability; soil

Abstract. *The olive tree is one of the most extensive crops in the Mediterranean that has a great social and economic impact. The method of obtaining olive oil generates effluents and organic materials that constitute a great economic and environmental problem in the olive sector and require effective and committed management, to guarantee the efficiency of the producer sector, environmental sustainability and improve the value chain.*

Agriculture faces the enormous challenge of feeding a global population of more than 6 billion people. For this it is necessary to achieve resistant crops in a sustainable way for which it is essential to have adequate fertilization and biostimulation with bio-based products.

The general purpose of our research has been the valorization of alperujo as a residue from the extraction of olive oil, in biofertilizer through its transformation with saprobios fungi , for the improvement in the fertilization processes of degraded ecosystems and the reduction of the environmental impact of the indiscriminate accumulation of alperujo.

1. INTRODUCTION

Intensive agriculture, characterized by over-tillage of the soil, intensive crops, and the use of synthetic pesticides and fertilizers, is degrading soils and reducing their organic matter content. Additionally, the excessive and indiscriminate use of synthetic chemicals causes the accumulation of toxic residues in soil and water, posing a potential danger to both humans and the environment (Scotti et al., 2015). Consequently, there is a demand for the development of sustainable strategies for the maintenance and improvement of soil structure and fertility in conjunction with increased crop productivity (Larney and Angers, 2012).

The application of organic soil amendments has been proposed as an effective way to restore soil fertility and, at the same time, protect the environment, as their use could be part of a strategy to eliminate and recycle waste (Medina et al., 2011). The application of organic soil amendments has been shown to produce changes in physical, chemical and biological fertility (Thangarajan et al., 2013). The continuous release of nutrients from the amendments can maintain microbial activity and biomass for longer periods of time, and thus increase the availability of nutrients for plants.

The olive oil industry has great social, economic and ecological importance in the Mediterranean countries. One of the main challenges of this industry is the management of the waste generated during the olive oil extraction process, since they are generated in a limited period of time of three to four months and have micro and phytotoxic characteristics (Ntougias et al., 2013). The al-

peorujo (DOR) is the waste produced by the olive oil industry after the two-phase extraction system and from which 5 million tons are generated annually in Spain (Siles et al., 2014a). Therefore, and so that a serious environmental problem does not arise, the appropriate strategies must be found for the management of this residence. One of the strategies that has been proposed for the management of the DOR is its use as an organic amendment.

2. USE OF ALPEORUJO (DOR) AS AN ORGANIC AMENDMENT

DOR is a residue characterized by its high content of organic matter and some agronomically interesting cations such as K, P and Ca, as well as the absence, unlike other organic amendments, of heavy metals and pathogens (López-Piñeiro et al., 2008). Its application to soil has potential benefits as an organic amendment to improve the levels of organic matter of degraded soils or as a strategy for the remediation of soils contaminated with heavy metals (Siles et al., 2014b; Hovorka et al., 2016). However, untransformed DOR contains high levels of polyphenols so its direct application to the soil can produce alterations in the physical and chemical properties of the soil and have toxic effects on both soil organisms and plants (Sampedro 2009 and García-Sánchez et al., 2012).

3. TRANSFORMATION OF ALPEORUJO WITH SAPROBIUM FUNGI

There is evidence that phenols are primarily responsible for the phytotoxicity and microtoxicity of DOR (Justino et al., 2012). Therefore, the transformation process of DOR should include the biodegradation of phenols and other potential toxic compounds, as well as an increase in the rate of humification of its organic matter. Among the processes proposed for the transformation of the DOR is composting, however the optimization of the same is not always easy and successful and also requires long periods of time (Pardo et al., 2017). Another method of treatment of DOR is its biotransformation by saprob fungi (Fig. 1). It has been shown that some saprob fungi in the soil are able to biotransform this residue since they present an effective enzymatic system useful for the degradation of a wide range of toxic compounds.

Fig. 1. Biotransformation process of the alpeorujo by saprob fungi

4. EFFECT OF DOR BIOTRANSFORMED BY SAPROB FUNGI ON PLANTS

Untransformed DOR adversely affects seed germination, plant growth, as well as chlorophyll a and b content and photosystem II efficiency (García-Sánchez et al., 2014). However, when the alpeorujo is applied after its biotransformation with saprobous fungi, not only do all these harmful effects disappear, but a promotion of plant growth is observed in the short term. The decrease in the phytotoxicity of biotransformed DOR has been related to the decrease in its phenolic content due to enzymatic oxidation and polymerization processes of simple phenols, which carry out fungal oxidoreductases (Reina et al., 2016). The detection of an improvement in plant growth in the short term after the addition of an amendment with biotransformed DOR is probably a consequence of the enrichment of the soil with nutrients important to plants, which are released from the biotransformed DOR and which are efficiently used by plants.

5. EFFECT OF BIOTRANSFORMED DOR BY SAPROB FUNGI ON SOIL

After biotransformation the DOR becomes an ideal organic amendment for the soil, especially in the Mediterranean region, where many soils are experiencing a clear degradation process. The addition of this residue as an amendment generates a significant and immediate increase in the content of total organic matter and dissolved organic C in the soil, as well as an increase in the content of K, a mineral that plays an important role in the stress tolerance of plants (Siles et al., 2015). The benefits of using transformed DOR as a strategy for the restoration of degraded soils through increased levels of organic matter are therefore demonstrated.

In addition to the physico-chemical properties of the soil, it is interesting to evaluate the impact of the application of biotransformed alpeorujo on the behavior of soil microbial communities. It has been highlighted that changes that occur in the soil in the first weeks after the application of organic amendments influence the nutrient supply for the plant in the long term, as well as the sustainability of agricultural systems (Tatti et al., 2013). In this context, Siles et al. (2014b, 2014d, 2015) investigated the bacterial and fungal response of soil following the application of DOR transformed by F. floccosa and F. oxysporum in terms of abundance, diversity and community structure using various methodological approaches. Bacterial and fungal biomass increased immediately after application of the transformed residue, as well as in fungal/bacterial ratios. However, the applications of the transformed amendments did not produce changes in bacterial and fungal diversity however they did cause changes in the structure of microbial communities. The bacterial and fungal communities of the soil appear to follow a trend of recovery of their initial structure after two months of amendment as demonstrated using DGGE and pyrosequencing-based analyses, which may have been related to the resilience of the soil. In addition, these authors demonstrated that the aforementioned changes in abundance and structure of bacterial and fungal communities occurred in parallel with changes in soil functionality.

6. CONCLUSION

It has been shown that the transformation of DOR with saprob fungi of the soil is an efficient method to generate a biotransformed product with appropriate properties to be used as an organic soil amendment. After the biotransformation process, the new product generated has a high content of stabilized organic matter, as well as some important nutrients and is characterized by the absence of phytotoxic properties due to the elimination of the phenolic fraction. Numerous studies have shown that the application of this transformed DOR to the soil results in increased plant growth in the short term, probably as a consequence of enriching the soil with fresh organic matter and essential nutrients. On the other hand, the application to the soil of transformed DOR increases the abundance of bacteria and fungi, has a limited impact on the structures of the microbial community and increases the activity of soil microbial enzymes.

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II (INTER)NATIONAL BIOMIMICRY WEEKEND
Esadapress editorial
Granada, 5-7 November, 2021

BIOMIMICRY AND BIOINSPIRATION AS A PART OF THE EDUCATION IN THE FIELD OF DESIGN IN SLOVAKIA

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Keywords: Biomimicry, Biophilia, Education, Design, Innovations, Interiors

Abstract. *The aim of the paper is to introduce selected bioinspired projects and activities related to Biomimicry in Slovakia basically focused on education in the field of product and interior design, innovations that were developed in an academic environment, and educational activities focused on young professionals and start-ups. The story of biomimicry start-up Biocultivator, diploma theses from the field of interior design where the authors inspiration was on the intersection of biophilia, biomimicry, and sustainability, as well as selected output from the course assignments where biomimicry was practiced as the main method for design, will be introduced in a form of case studies.*

1. INTRODUCTION

The influence of nature on art, architecture, design, and science throughout history, from the period of industrial revolutions to present times, represent a very important aspect of design evolution. From a certain point of view, nature-inspired creativity is leading to strong design stands between science and art. Bioinspiration together with all approaches like biomimicry, biophilia, and biomimetics, is one of the design strategies which changes the paradigm of current design towards the systematic approach and sustainable, innovative, and hybrid thinking. This paper deals with methods of bio-inspired design in several case studies basically from the academic environment. The first part briefly introduces the author's work - Start-up project Biocultivator, and design projects from the academic environment and practical applications, which were created based on biomimicry methodical procedures and theory of nature-inspired design creation. In the presented projects from the academic environment, the focus was placed on teaching the method of BIOMIMICRY in the subject Ecology versus Design. The primary purpose of this article is to present outputs of teaching to show opportunities to teach bioinspiration methods and Biomimicry principles to students with variable backgrounds interested in environmental sciences and design subjects. The presented collection of students' projects includes the final thesis as well as semestral assignments. In projects will be shown the diversity of creative approaches used by students. While working individually or in groups under time constraints to complete their projects, they addressed given assignments differently and delivered exciting outputs. Team size, students' skill sets, seniority, and expertise, also influenced project outcomes. The developed teaching methodology was proven to be highly effective in addressing sustainability issues by interdisciplinary teams through bioinspired methods. Knowing the bio-inspiration processes from different design perspectives allows an understanding of the practice and automation of bio-inspired thinking in design.

2. AUTHOR'S START-UP PROJECT BIOCULTIVATOR

In spring 2015, the "Five for Life" team from the Technical University in Zvolen, Slovakia participated in the Biomimicry Global Design Challenge for which they developed the concept of the Balcony Cultivator. The biocultivator was conceived as a path toward sustainable living for common people residing in contemporary apartments with no access to their own garden. They aimed to develop ways for regular balcony gardening. The developed prototype was successfully selected as one of the seven finalists from all over the world. Additionally, the Balcony Cultivator won the People´s Choice Award which encouraged the team to continue the development. In 2016, they founded a start-up company B4D (biomimicry for design). Finalists were invited to participate in a one-year accelerator program supported by the Biomimicry Institute and the Ray C. Anderson Foundation (Interface) which facilitated further development of the team's concept into a new product, the Biocultivator— an innovative bio-inspired balcony greenhouse with integrated vermicomposter for urban areas. The product provides cultivation & innovative organic design; integrated smart system; vermicompost; production of own fertile soil & organic liquid fertilizer; the system produces its own electric energy; self-irrigation is ensured by passive biomimetic water collection (Gejdos 2017) (Commans 2015). The Biocultivator provides a simplified view of how an ecosystem, or the entire biosphere works. The system uses the heat energy generated by the vermicompost for the stack effect, meaning hot air rises and is a trigger for cooling the system from the bottom up during hot summer—a passive ventilation system. Team focused on the product on the system level and studied the concept of circulation of the water and nutrients in ecosystems. Small forest ecosystems inspired B4D in terms of keeping water and temperature in balance. The semi-closed ecosystem in the Biocultivator was designed based on the inspiration taken from the water circulation and decomposition processes in nature. The biowaste in the forest is used as "food". Decomposing processes are accelerated by the synergic actions of microorganisms, fungi, worms, insects etc. Decomposing of the biowaste generates heat which, in turn, supports evaporation. The small water droplets are condensed on the tree leaves and rocks. The water in the proposed system of biocultivator originates mainly from the water amount in the compost. The user needs to add little water to the system. By evaporation, this water is collected and recycled by condensation on the inner surface of the cupola. The compost itself is a living organism and represents "home" for the colony of worms that are decomposing the waste in the Biocultivator four times faster than in regular composters. Worms are producing both the organic liquid fertilizer which flows into the drawer on the bottom of the product, and the solid parts that are used as fertile hummus during the growing season—ensuring water and nutrient circulation in the whole system. The innovative idea is based on utilization of all elements that are cycled in ecosystems.

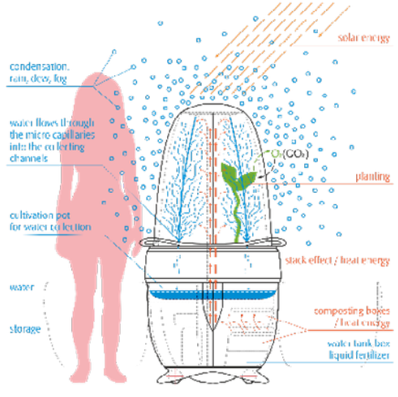

Fig. 1: Scheme Biocultivator (source: author)

Fig. 2: Scheme Biocultivator (source: author)

3. INTEGRATION OF BIOMIMICRY INTO THE FURNITURE AND INTERIOR DESIGN CURRICULUM IN THE FORM OF COURSES.

Circular economy and methods of nature-inspired design thinking and other eco-design tools are part of lectures and following studio assignments at the Department of Furniture and Interior Design. Course title is Ecology vs. Design – the course unit code: EVSDI-V. Instructor: Zuzana Tončíková, (associate professor). Planned learning activities and teaching methods: lecture: 2 hours weekly / 26 hours per semester; studio: 2 hours weekly / 26 hours per semester. Students are from the program Design of Furniture and Interior - bachelor (full-time), 4th semester. The course is project-based. The theoretical part of the course provides basic information regarding the terminology and philosophy of design for sustainable development inspired by nature. The main studio project of the semester is focused on the biomimicry method and its application. Other eco-design tools serve as support to improve the final bioinspired concept. Biomimicry Project Outline: Three presentations & lectures and partial projects. Initial warmup exercise is small assignment when students spent a half-hour in nature where they observed and then described basic biological surroundings. Students could work on their final projects for approximately twelve weeks.

Presentation part 1: The first lecture introduces the impact of nature on art, architecture, design, and science across history. It presents an exciting point of view on the possible future of sustainable innovations. The lecture explains methods of bio-inspired design thinking, including Biomimicry. The last part of the lecture focuses on the essential element of Biomimicry - Ethos. The first partial assignment was related to this element.

Biomimicry Project 1 - Life Principles (LP)

Each student chooses one of the 26 life principles presented in Biomimicry presentation 1

The task is to look for organisms in nature whose survival is based mainly on a given principle of life, and it will serve as biological example.

Based on the selected biological example, the student found an illustrative (metaphoric) human design example of the chosen life principle.

The presentation - Part 2: The second lecture focused on a Biomimicry practice. Students were familiarized with two essential elements of Biomimicry, re-connect and emulate. This presentation explained the process of reconnection with nature and the mechanism of emulation.

Biomimicry Project 2 - Function Cards (FC)

- Students were instructed to create individual Biomimicry Function Cards
- From the previous project related to the Life Principles, each student selected one organism.

Based on the deep understanding of how this organism survives in its environment, they identified the most significant function and strategy used by this organism. Then the detailed description of the mechanism and how this organism performs X or Y function followed.

- The next step was to abstract the concept of design principle from the identified mechanism, stripped of complex biology for clarity and understanding. The goal was to create "an instruction to design with a given function."

Biomimicry final project 3: GROUP PROJECT

The final project was assigned according to the Design Brief of Biomimicry Global Design Challenge 2021. The intention was to motivate and prepare students for submission of their Biomimicry final project to the competition. Teams of 4-6 members were created to cooperate.

Project Challenge: Create a nature-inspired innovation (a product, service, or system) that aligns with one or more of the Sustainable Development Goals, outlined by the United Nations while incorporating all three essential elements of biomimicry into your proposed solution.

3.1. PHYTOWHALE

The phytoplankton cycle is a nature-given biological pump. Marine mammals like whales dive deep into the water to feed and then rise to the surface to breathe. By doing so, they create a whale pump that mixes layers of the ocean. This movement causes the movement of nutrients in deep water to circulate to the surface, illuminated by the sun´s rays, which helps phytoplankton grow and support the food network. Phytoplankton is able to develop only in photic zones of the ocean where it absorbs CO2. But in time it sinks to the bottom of the ocean. Whales that feed in the twilight zone move up and down through the water column, thus providing vertical mixing of the water and the phytoplankton breaching into the photic zone. This biological process becomes the main source for inspiration and abstracted into the underwater drone which helps to develop resources of phytoplankton when there are not enough whales because of their continuous extinction. More phytoplankton means more whales. Like the whale, the drone moves in huge ellipses up and down to move plankton to the photic zone. The key is a movement in a shoal. The concept consists of multiple autonomous drones that mimic what whales do (fig. 3). The concept is designed according to the aerodynamic shape of the body of this beautiful mammal. Three large fins are used for movement. A large horizontal fin provides forward propulsion. The side wings control the direction of the drone. The entire body is made from carbon fibre panels that incorporate supercapacitors that serve in place of a battery. Supercapacitors charge by solar panels on the top of drones. Other biological principles which were integrated were taken from nautilus (diving) and tuna fish (complex synchronized coordinated behaviour).

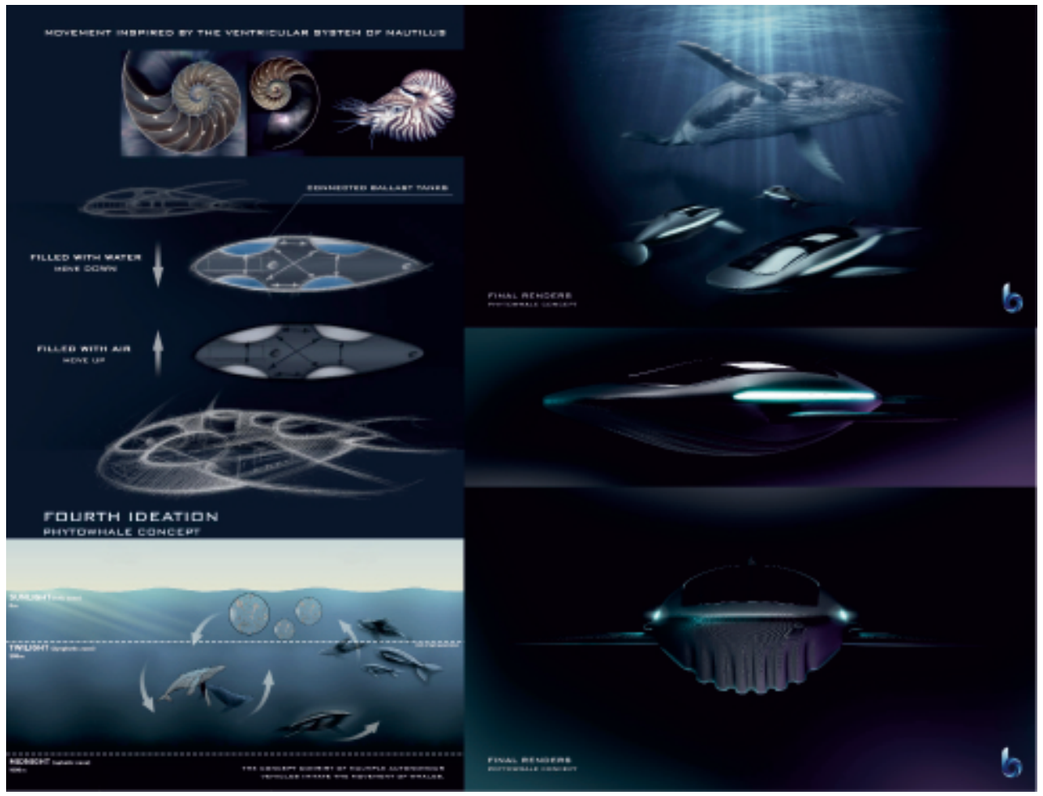

Fig. 3: Phytowhale concept (source: author´s library)

4. INTEGRATION OF BIOMIMICRY AND BIOPHILIA INTO UNIVERSITY EDUCATION AS A PART OF FINAL THESIS RESEARCH METHODOLOGY AND SOURCE OF INSPIRATION

If students want to continue with biomimicry, they have opportunity at the Department of Interior and Furniture Design TU in Zvolen to apply as BC. or MSc. students for the final thesis with topics related to biomimicry and biophilia. Then they have available one year of one-to-one consultations with experts to integrate biomimicry into their final thesis. The following project was selected as an example of good practice.

Diploma thesis - Topic: **Biophilia in space**; student: Barbora Kolencikova, supervisor: assoc. Prof. Zuzana Toncikova, ArtD.

Understanding human evolution in the natural environment has become the basis for the formation of biophilic design, which is applied in the thesis - Biophilia in space. The thesis aims to look into offices of the future, which innovatively change their functioning and focus more on the man, his needs, perceptions, and feelings. Using the principles adopted from nature, we create an innovative coworking space that functions as a living ecosystem. Space, which is subject to constant development, creates an intimate connection between the environment, and the community. We strive to connect quality workspace with natural principles, resulting in the total labour effectiveness and psychological well-being of people. The thesis brings a new perspective on the recycling of an abandoned building. The conversion of existing building of former canteen at Faculty of Architecture in Wiesmar in Germany into new coworking spaces is a metaphorical and artistic embodiment of metabolism while reusing the potential of the existing architecture concerning authenticity and historical background. Beside methods of Biophilic design the main biological inspiration was taken from the ability of bacterial biofilm to survive. Bacterial biofilms are clusters of bacteria that are attached to a surface and/or to each other and embedded in a self-produced matrix. In addition to the protection offered by the matrix, bacteria in biofilms can employ several survival strategies to evade the host defense systems (Vestby 2020). Within the biofilm, the bacteria adapt to environmental anoxia and nutrient limitation by exhibiting an altered metabolism, gene expression, and protein production. All their strategies were studied and in metaphoric way integrated to the design of interior which main role is to protect cells (evolving start-ups) inside the system (interior). The result of the practical part is the solution that takes over naturally proven strategies of operation. Nature becomes the driving force of space. Thanks to its principles, a flexible working environment is created that can be easily transformed and adapted to the current needs of its users.

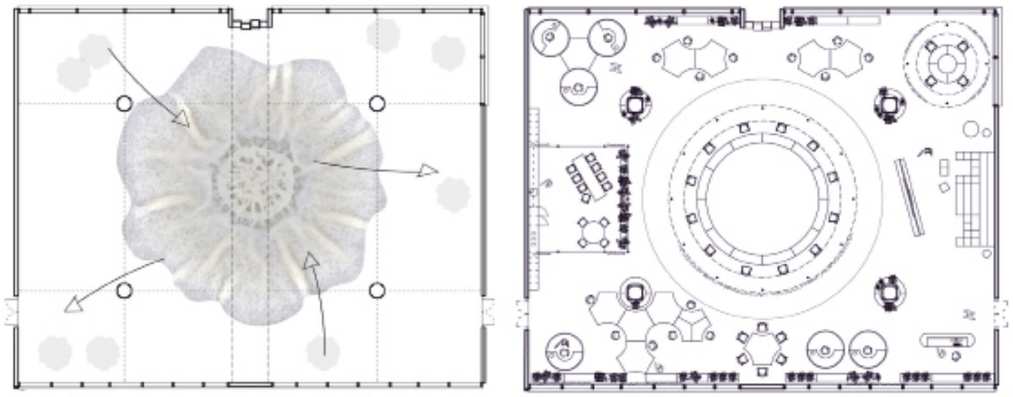

Fig. 4: Diploma thesis project by B. Kolencikova (source: Author)

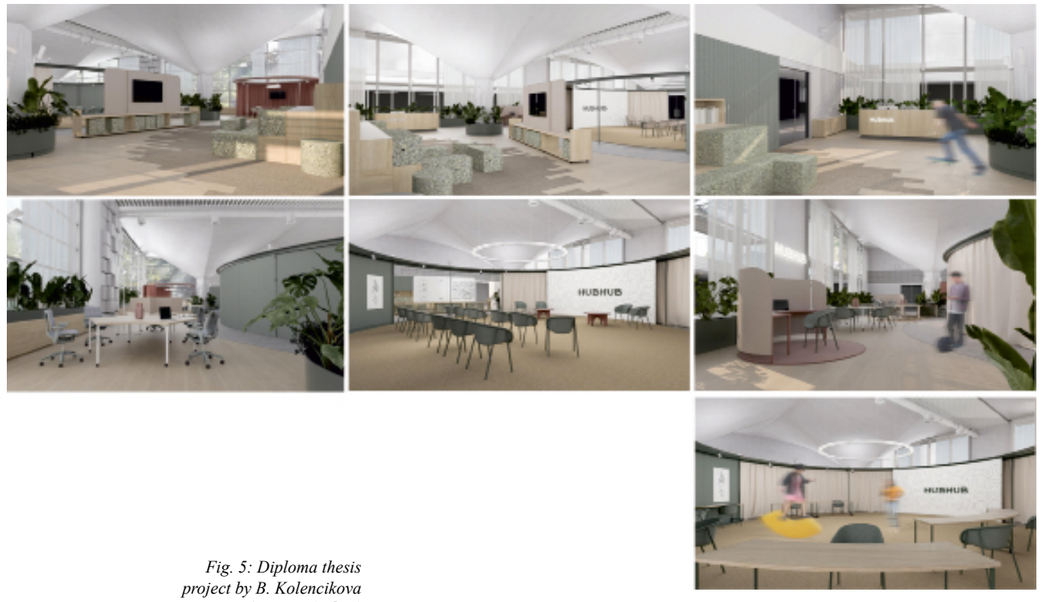

Fig. 5: Diploma thesis project by B. Kolencikova (source: Author)

5. EDUCATION & BIOMIMICRY FOR PROFESSIONAL INNOVATORS IN SLOVAKIA

In Slovakia currently exists two platforms for professional implementation of Bioinspiration and biomimicry into the start-up ecosystems and among professionals dealing with sustainable innovations. One is Lifbee Academy. The program connects interdisciplinary cooperation scientists, environmentalists with marketers, designers, computer scientists, and entrepreneurs. In 8 months of education, they will learn the process of creating a biotech product by using different tools of Biology including Biomimicry and bring solutions to the problems - real challenges and real impact. Lifbee partners actively participate in various activities, whether it is evaluation during the project phase, assignment of topics, or professional participation in lectures. The second initiative is the platform Mirror Nature in form of a workshop intended for professionals from different environments. This workshop initiative is supported by partners such as the Slovak Centre of Scientific and Technical Information.

6. CONCLUSIONS

From a certain point of view, nature-inspired creativity leads to the robust design stands between science and art. Bioinspiration is one of the design strategies which changes the model of current design towards the systematic approach and sustainable, innovative, and hybrid thinking. These selected projects from the academic environment demonstrate the exciting approach of bio-inspired design thinking. The core of the projects deals with the detailed introduction of biomimicry methods and so-called life principles. As a part of activities focused on the education of students are organized the short time biomimicry workshops as well. It is a valuable activity that serves mostly as a tool for the first introduction of Biomimicry to students. But according to the experiences because biomimicry is not simple, method semestral courses (subjects) are much more effective because by this way Biomimicry is a serious part of the curriculum and wider competencies in design for graduates. Knowing the bio-inspiration processes from different design perspectives allows an understanding of the practice and automation of bio-inspired thinking in design, which will play a significant role in design bio(r)evolution for

decades to come. The feedback from students and their willingness to apply these methods of bioinspiration into their professional life after graduation is in this case the most valuable reward for teachers and instructors.

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II (INTER)NATIONAL BIOMIMICRY WEEKEND
Esadapress editorial
Granada, 5-7 November 2021

PLUMBUM PROJECT: A CIRCULAR ECONOMY INITIATIVE RECOVERING LEAD FROM THE SEA TO RETURN IT TO THE MANUFACTURING CHAIN. GIVING A NEW LIFE TO RECOVERED FISHING WEIGHTS

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Keywords: Fishing weights, lead, ghost nets, marine pollution, circular economy, design thinking, deep ecology, circularity, social responsibility.

Abstract. *Fishing weights, divers' belts, fishing boxes, balance boating are human activities and artifacts that use lead (Pb) for their manufacture. The Plumbum project started in 2017 as a volunteer diving initiative and collected nearly 13,000 lead pieces from the seabed. This is more than one ton of lead that is now 90% back into the production cycle.*

This workshop increased visibility on the sustainability of the entrepreneurial initiative and a complementary regenerative design perspective was offered by presenting an approach known as the hexagonal model, which describes a way to start a new design thinking approach. Several ideas to replace fishing weights were presented and some ideas for upcycling or reusing lead resulted and are presented here.

1. INTRODUCTION

Fishing, boating, and diving are activities humans have been engaging in throughout history, especially sailing and angling. They date to at least Roman times or before in the Mediterranean. Rod fishing (angling) is very popular across the Mediterranean islands and coasts.

Lead (listed as Pb on the periodic table) has also been associated with fishing, boating, and diving industries for a long time. More recently heavy metals, like lead, have been recognized as marine pollutants. This recognition has replaced the old perception of "a cheap material" and the polluting dimensions have become more evident. Fishing weights are easy to lose or get tangled since good fishing spots are usually located on rocky bottoms, where entanglement is also more likely. Once tangled the fishing line and the weights are abandoned in the sea with hooks, nylon, bait, and lure. Fishing nets are also discarded, leading to large ghost fishing nets creating a serious marine problem occurring not only in the Mediterranean but worldwide.

Lead remains relatively stable under marine water conditions, but it is a good substrate for algae growing or for sessile invertebrates which are looking for a clean surface to establish or settle. These algae start growing on the lead surface, similar to a lichen growing on top of a stone, and fishes, urchins, crustaceans, mollusks which feed from those algae scrape and graze the lead surface while eating algae. Some lead particles might be eaten by them while feeding. In this way the lead is introduced to the marine food web and starts increasing the toxicity for living marine organisms.

In parallel there is the cost of extraction, energy, transformation, and manufacture of lead. While its uses in fishing can be replaced, lead remains one of the most important metals to industrialized economies[1]. More than 80% of lead is used in battery manufacturing and the other significant uses of lead are in ammunition, oxides in glass and ceramics, casting metals, and sheet lead. Demand for lead worldwide is expected to grow largely because of increased consumption in China, which is being driven by growth in the automobile and electric bicycle markets[1].

2. OBJECTIVES

This work has several aims which can be stated as follows:

1. Raise awareness of ocean contamination – especially the lead issue and draw attention to bioaccumulation and magnification in food webs and ecosystems caused by heavy metals mismanagement.
2. Demonstrate the potential of using lead derived from fishing weights as an input (raw) material for use in the market.
    a. Identify possible opportunities for upcycling
    b. Create spaces for connecting interested parties from across diverse economic sectors and disciplines

This paper also wants to introduce The Plumbum Project (Spain) to a wider scenario in the EU and internationally. Linked with the Green 2021 conference, this initiative is offering an understanding to raise awareness on the process and principles of regenerative and circular design in systems and material metabolisms, offering a unique opportunity to create a space for creative brainstorming on the marine pollution problem that has been presented here.

3. METHODOLOGY

In this workshop, we planned to learn more about the complex challenges on marine pollution, specifically caused by lead weights, fishing lines and nets left abandoned or entangled during fishing endeavors as a global marine ecosystem hazard, additionally to the well-known plastic/microplastic ocean worldwide trash threat.

The priority focus during the workshop was to brainstorm positive actions and ideas that we can take to raise awareness of these issues and to know useful examples of what we can do with lead pieces so far removed from the sea (www.proyectoplumbum.com). Using underwater images, we showed the problem caused by fishing, boating, and diving while using lead and situations that show how easy it is to lose or get tangled long term on the seabed creating a huge problem.

After this, a very brief presentation on regenerative design and upcycling theory was presented. This presentation introduced topics such as:

- A hexagonal design model leading to regenerative design,
- Ideas from deep ecology and the donut economy,
- An overview of circular systems,
- The current material cycle,
- Technical and biological upcycling life cycles,
- Root problem analysis

To close the session, we asked for a collective conclusion sharing points of view and opinions

[1] *https://geology.com/usgs/lead/*

about the workshop and made an invitation for further networking. Attendees were invited to visit the display of weights, fishing line and nets, photos and on the first floor of ESADA, and to visit Plumbum website presentation online.

Figure 1. Fishing weight on the sea bottom and a Gobie fish on top, look at the Urchin's spines on the left, they are one of the most common invertebrates close to lost fishing weights.

4. DISCUSSION

There is little awareness of this problem. The Plumbum Project (Figure 3) started in 2017 and it has been very active since, recovering more than 1 ton of lead from the sea bottom. 950 kg. of lead are already back into the production cycle. (Figure 4) Volunteering Página divers are happy to collaborate on this initiative and this project has already received some awards and acknowledgement for its work recovering lead from the sea bottom. The project was also recognized for creating a new source of this valuable material resulting in a triple positive effect: (1) minimizing the seabed pollution, (2) recovering a valuable material from the sea and (3) reincorporating it into the supply chain for making new products. We can add that some enterprises have started to show interest in their social and corporate responsibility to support this initiative.

How can we avoid entering or losing lead in the sea? This question was posed to start discussion during the workshop and, one idea was to replace the fishing weights with ceramics or cobbles or pebbles or even by Zinc (Zn). New alternatives for lead substitution in fishing are already ongoing. The discussion showed that it is necessary to work simultaneously on recovering lead from the sea bottom, but also to replace the use of lead on fishing weights to avoid new inputs as marine pollutants. There is also a need to improve legislation and standards to be enforced and to modify administrative and legal procedures regarding lead use for fishing and marine usage (similar to cases of hunting on land). Since lead is a valuable material, co-

llecting it from the sea is worth the effort. During this workshop some alternatives for re-use were presented. Some ideas from regenerative design and upcycling theory were mentioned to understand new possibilities better (Figure 5).

5. CONCLUSIONS

The Plumbum Project has removed more than 13000 pieces, 1000kg, of lead from the sea by hand, using underwater metal detectors (See photo attached). There are some ideas for reuse, recycling, upcycling, and offering some different uses for a true lead use/recovery transformation. One of the most relevant and common ideas from regenerative design was to use lead as an object assembly, like a modular weight for home use as washable ankle/wrist and door weights.

Since diving for lead recovery is an expensive and plodding activity, it needs support for its enforcement. Corporate Social Responsibility groups within enterprises can be seen as an economic mechanism that could help this initiative, even more now that batteries for electric cars are growing in demand as well as other devices like drones, mobile phones, etc. X Ray protection jackets manufacturers (made from lead) are also another industry that may be interested in creating a blue brand while making their vests from lead recovered from the seabed and acknowledge the circularity with a clear message on blue circular economy

New regulations are also an addional line of effort, which can offer a possibility to move from the old lead fishing weights to the new ceramic fishing weights that are closer to nature and mimicking heavy non-toxic materials in living systems. It is time to start implementing all of these perspectives and ideas.

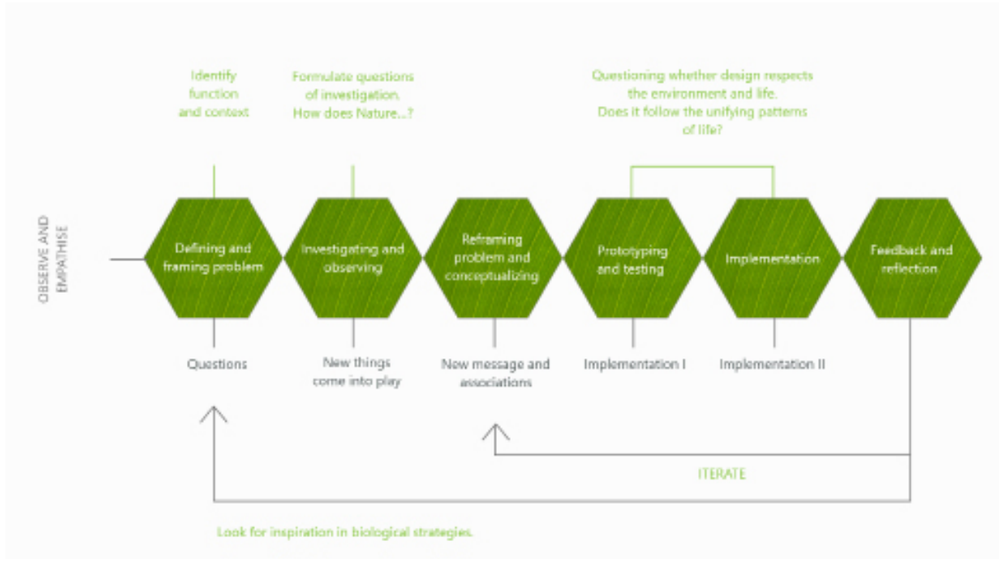

Figure. 2 hexagonal MODEL SHOWING the approach to circularity on regenerative design. by a. steensma

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PHOTO ANNEX

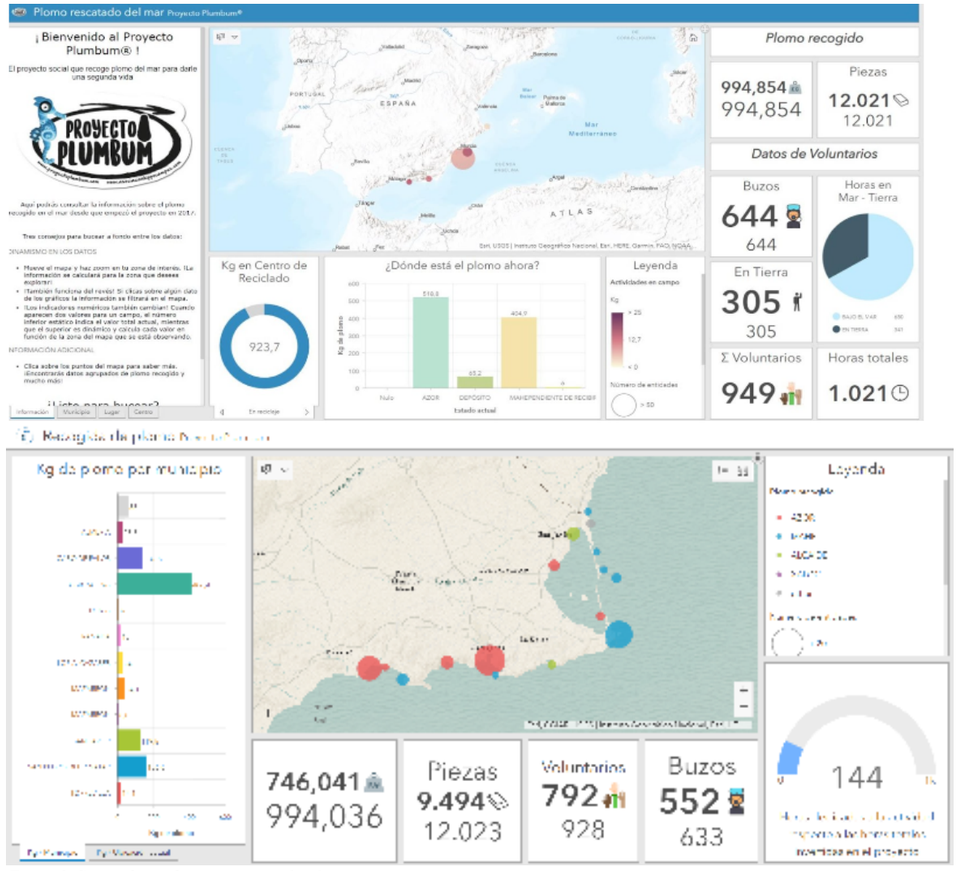

Figure 3. Screenshots of ***www.proyectoplumbum.com***

Figure 4. Fishing weights recovered from sea bottom, ***www.proyectoplumbum.com***

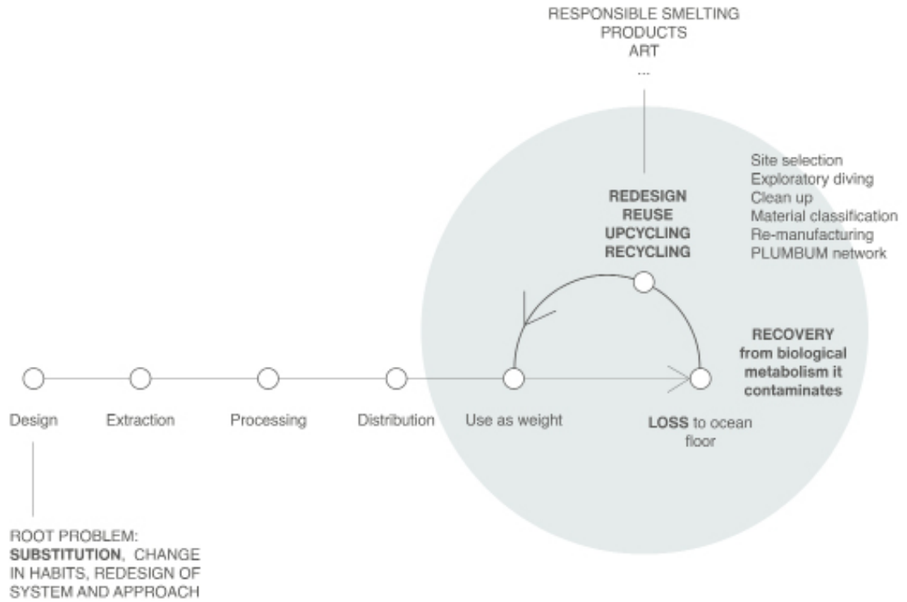

Figure 5. Plumbum Project and regenerative design model approach. By A. Steensma

II (INTER)NATIONAL BIOMIMICRY WEEKEND
Esadapress editorial
Granada, 5-7 November, 2021

THE POWER OF IMAGINATION IN SUSTAINABILITY COMMUNICATION

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Keywords: imagination; visualization; communication; change

Abstract. *Imagination and the visualization of our dreams, fears, and plans for the future is something that has always helped humans to progress and advance and, in a way, it shaped our species and civilization. Today more than in any other time this ability is needed to be able to visualize and imagine a different civilization. A different future we can test it in our imaginations first and then share it; visualizing why it is important and worth the change. This is a fundamental ability for those working in sustainability and with change at different levels. It's a fundamental skill for communication professionals who are called to support change-makers and inspire more and more people to look at the future with an open mind and wonderous eyes.*

Our ability to imagine a more sustainable future is connected to our ability to visualize different things: the problems, the solutions, the gap between the two, the risks of our inaction, and the path to follow. These should be strategies to show the urgency of the task at hand but also the opportunities that these changes can bring to improve our societies and our lives.

1. ARTICLE

How humanity looks into the future and the stories that this activity generates is something that has always fascinated me. I started when I was at University studying how humanity was using science fiction to tell powerful stories about our fear of mortality and the future. Then I got involved in the challenge of communicating the sustainability challenge. Here too, the future is front and centered and the stories we tell or hide are what might shape and decide how we act.

A few years ago, I was traveling in Mongolia and we arrived in a place called Khongoryn Els. There is a line of dunes that emerge from the otherwise flat steppe. Our guide told us that climbing the dunes was a fun activity for tourists. You could climb the dunes at sunset and then come down. She didn't add more. So, with my husband, we started climbing. It was one step up and two down because the sand was moving under our feet. It was so hard. The landscape was nice with the sunset, but nothing life-changing. It was still the flat steppe. And so after a few hours, we decided we had enough and came back down. At night, back in the ghers, the Mongolian tents, we saw the video from another tourist who climbed to the top and we were shocked by the view on the other side. Those sand dunes were the door to the beginning of the Gobi Desert and dozens of golden dunes were on fire at sunset. Beautiful! but we didn't know that before and we didn't endure the strain of climbing the dune because we didn't know the view would be so powerful and unique.

A few months after, this memory came back to me when thinking about how to motivate people to change and to make sustainability choices. Many times, the mistake we make is focusing a lot on the urgency of the difficult task but we fail to put in the effort to communicate the bigger context

and to share the beautiful outcomes of that change or that sustainability project. As a result, we fail to motivate people enough and we fail to tell them about the journey and the community of people that will share that journey with them.

So, I started collecting good practices of visualization and imagination building that are related to social and environmental communication. All of them can be classified into some groups of strategies that it would be useful to always keep in mind when building a communication strategy related to sustainability and change.

- **How are you visualizing the problem?** This is not just about sharing a number or a shocking picture, it's about really visualizing what that number means, the consequences, the size of it compared to things we know, and also making it relevant for the reader where and at the moment where they are. If a problem is far away, make it closer for viewers, if it's too big or incomprehensible bring it down to their experience.

  A couple of beautiful examples in this sense are the visualization of the carbon equivalent emissions of a city like New York that Carbon Visual did a few years ago and the campaign by Amnesty International on torture.
- **Are you visualizing the connections?** We are all trying to solve systemic problems and sometimes the first step is to understand the relationships that one problem has with others. How are things influencing each other? How by touching one we can improve many.
- **Are you visualizing the gap and the cost of inaction?** Sometimes we react and act in autopilot mode because we are too busy to think about consequences or those consequences are taking place far away in time and space. That gap needs to be visualized and told so that the consequences of our inaction in the face of a problem are clear and can be evaluated.

  One of the best examples I know is this experiment by Fashion Revolution to show what is behind a 2 euros t-shirt and let people decide if to purchase or donate.
- **Can you use art and Nature to inspire?** Art has the advantage of not being bound by science or by social restrictions. It can explore the future more freely; it can free the imagination and it can make the abstract visible in beautiful ways. Art is like a playground for our imagination and so it should be a playground to experiment with the problems that humanity is facing and their consequences. Nature can inspire us in other ways. As is often said, nature has millions of years of research and development on her side and can offer the best solutions to many problems. But it can also offer an experience that we are rapidly losing. The experience of being connected, and being part and in an ecosystem where there is no away, there is no acting independently.

  A great example of the use of art is the Human Sensor project by media artist Kasia Molga and developed with Professor Frank Kelly of the King's College London. The experiment was done in 2016 in Manchester. Performers in hi-tech illuminated costumes were walking through the city during one day and with their sensors on the costumes, they were revealing changes in urban air pollution.

  For inspiration from nature, every project developed starting from the concept of biomimicry is a great example. There is a great collection of biomimicry solutions on the Ask Nature website by The Biomimicry Institute.
- **Did you explore unexpected associations?** Did you try to flip the script? It's clear now that many of the things we have based our social and economic systems on are not working anymore. So, the most interesting findings and explorations come from flipping these scripts. What if waste was a resource instead of a problem? What if we made meat without killing? What if we packaged without the packaging? Or what if money was something different or had a different purpose? These are powerful questions that can offer innovative lines of thought and solutions.

  Some great examples of brands and companies that have flipped the script are: the Italian company Aquafil, with their ECONYL(R) regenerated nylon coming 100% from waste; Notpla producing packaging that you can eat; Modern Meadow with leather produced without killing animals; and Impossible Burgers producing a burger without killing cows.

And when it comes to rewriting the script on money, Sacred Economics by Charles Eisenstein is your sacred entryway into this fascinating topic.
- **Are you using all human strengths and the richness of our way to communicate socially?** As humans, we have placed a lot of power in the written and spoken word, but a message is conveyed using many different channels and senses. And when building a message of change, that often requires also social changes, we cannot forget to include in our message a richness of tools and media. Back to the metaphor of the dune, there was a great community of people toward the top of the dune that was sharing the beauty of the view and celebrating the efforts of getting to the top and even opening some bottles of red wines to share with others while enjoying the sunset. This could also have been a great way to motivate people who were still climbing.

When we talk about sustainability projects it's important to underline the changes that they can bring to our communities, the healing power, the emotions, the fulness of the experience with a community of like-minded, and the beauty of sharing such a journey with others. These are things that can really make the hardness of the journey and the difficulties lighter. So, this means that we need to share the fun activities, the meals, the experiences of the senses, the gatherings…

Another point that really fascinates me is how narratives are changing. It's a slow process but it's there. The story of the lonely hero is not as powerful as it was in the past. These are times for different narratives, for collective and community narratives, for the Choir typical of ancient Greece and Rome, for the sharing of fireplace stories like the characters of the Decamerone by Boccaccio, where a group of young people were sharing stories while the pandemic was ravaging outside of the building where they were in lockdown. It's not easy, our society was built on the concept of the lonely hero and often choir or multiple-voice narratives can be more confusing to create. But it is part of the challenge because change needs a variety of voices, from the periphery, from indigenous people, from young ones and all the groups that are less used to the main narratives and can bring fresh ideas and visions to the table.

One example of creating an event around a project that is able to really make people experience the problem with their senses is this dining event by the NGO Smile Asia to raise awareness and donations for children with cleft lip and palate.

Back to my climbing of the dune. That journey is a great reminder of the power of vision and communities we are still not leveraging. This is a power that could make our sustainability projects and narratives much more effective and richer not just for those who initiate them, but also for those who pick up the torch and pass it to the next generation.

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II (INTER)NATIONAL BIOMIMICRY WEEKEND
Esadapress editorial
Granada, 5-7 November, 2021

CREATING WONDER IN SCIENCE

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Illustrations by Luisa Nunes

Keywords: Wonder; education; perspective; conservation; biomimicry

Abstract. *This short review presents the sense of wonder as a prerequisite for engagement with science, its role as a source of questions not only for students but for the public in general, and also its role as a prerequisite for learning, in the sense that it can contribute to a change in students' view of natural phenomena. To better understand how we can protect and respect the natural world, it is necessary to know it. Creating wonder about species, habitats and how they relate and function can be done not only through direct contact with these aspects but also through nature journalism, illustration and training in concentration or observation. This paper delves into the role that wonder and the subjects most closely associated with it, art, and science.*

1. INTRODUCTION

Often we tend to think that science involves facts and logic, and human feelings are overlooked or considered an obstacle to be eliminated. Nevertheless emotions are as important in science as they are in any other part of our lives. Science is done by humans, and as human beings, even if we try, we can't get rid of our emotions. So instead of fighting them, even in science, we should make use of our feelings, because for advances and innovations, they are as important as facts and logic.

Science must be based on facts and logic. When it is said that we use our emotions in science, it doesn't mean that we should use feelings instead of facts. The observer shouldn't be conditioned to use her feelings to implement and catalyze fact-based science and innovation. Emotions and logic are not opposed. They complement and reinforce each other. The feeling of dedicating to something significant, of belonging to something bigger and of being empowered is fundamental to creativity and innovation. Whatever we are working on, it's important to take the problem to the heart as much as we like (Ellerton & Brown, 2007).

An attitude of "admiration" cannot necessarily be identified with curiosity, a rigid distinction between a passive and an active aspect of admiration cannot be maintained. But even if such a distinction were maintained, and therefore an attitude of "admiration" was identified with a perplexed curiosity, science teaching would be in favor of fostering such an attitude, on the grounds that it promotes scientific inquiry, although they should not be concerned about the "wonder of" (Leonard & Harvey, 2007).

In the context of popularizing science, images are created to communicate ideas to a broader audience and are usually created by illustrators. In this case, images serve as carriers of

scientific concepts for a wider audience. Their role is to get attention, quickly familiarize people with the basics, and help them remember what they saw. These images are generally very attractive and spectacular, but are also focused on conveying complexity and precision. Their big advantage is that they are generally language independent and therefore more accessible. They are often based on or inspired by some versions of images taken or created in a purely scientific context, even though they look very different.

This proves that illustrations or art in general are an effective tool for science and other serious contexts. Far from being expendable "additions", they function as powerful vectors of scientific messages, concepts, and theories within and outside the scientific community. Its universal appeal can have a big impact on how science and research are perceived in society.

Many of us think of ourselves, humans, as separate from "nature." We forget, or, as urbanites in the modern world, we never knew, that we are deeply connected to nature and part of it. As we focus on the feel of our bare feet on the earth, we remember, or feel for the first time, our connection to the natural world.

To really connect with nature, we need to pay attention to our environment. But what if the observers are slow to get involved or don't get interested? In this case is necessary to capture their attention with activities that require careful observation, and a goal.

For students to want to discover, it is not only necessary to wonder, but also to have curiosity. As described by Opdal (2001), "Curiosity … is a reason to explore within defined and accepted frames" while "wonderful … provides doubt about the frames themselves". Thus framed, although curiosity may be enough to initially motivate a person to seek an answer, it is little wonder that it can cause the emotional investment necessary for in-depth investigation (Hadzigeorgiou, 2012). Amazement can therefore be inspired by curiosity, and curiosity takes two forms, diverse and epistemic (Limon, 2001). The first is based on the perception of one's immediate environment (Leonard & Harvey, 2007), it's the kind that's often seen pejoratively because that's what killed the cat or, in this digital age, the kind that inspires a person to watch YouTube videos of cats. The latter is the form you send us in search of answers, the one that takes us to the rabbit hole. This type of curiosity is often associated with achieving a specific goal or acquiring specific information.

2. ART AND SCIENCE

Art and science are a duality that heightens our perceptions and experiences of being alive, which leads us to wonder. The hemispheres of our brains working together must be complementary. Somewhere along the line, we decided to prioritize the left-brain over all brain thinking and perception. Maybe this is what explains why people feel disconnected from nature. There is something about the hard materiality of science as it may be taught that doesn't satisfy many. Science and art are not so different from each other. Each discipline may employ approaches that at first glance appear to be poles apart, but it is interesting to see (if given the chance) how much science and art can overlap.

Visual art has been used to document the natural world for thousands of years, from cave drawings of animals that help today's researchers figure out yesterday's fauna, to paintings of centuries-old experiments that show us how they were conducted. One of the most famous examples of the interconnection between art and science is the work of Renaissance master Leonardo da Vinci.

Beyond the use of art to document scientific progress, the English naturalist, Marianne North's paintings of tropical plants serve as both historic and scientific records. Active in the mid to late 19th century, North traveled extensively on her own, a feat unheard of at the time for a woman. She was never formally trained in painting, but her talent and productivity produced over 800 paintings that currently hang in the Marianne North Gallery in Kew Gardens, London. Her work transcends traditional plant specimens, which are collected, dried, preserved in herbaria and used to establish a record of species (EBSCO, 2017).

While those samples document discovery and provide a necessary historic record, North's brilliantly colored paintings bring those species to life in their natural habitats as part of their ecosystems. Charles Darwin considered North's paintings to be excellent examples of his theory of natural selection. One can see quite clearly from her work the adaptations that tropical plants have made to survive in different areas around the world, and the similarities between geographically close species (Ayala, 2017).

Many examples of art intersecting with science exist around us, but these few highlighted here illustrate how art is crucial in helping us understand our scientific legacy and how science is well served by applying an artistic lens. Together, art and science help us create wonder, interpret study, and explore the natural world around us.

With an emphasis on learning to see and observe, drawing nature doesn't require special skills, artistic ability, or even nature knowledge, and it is a tool everyone can use to record observations and experience the benefits of a stronger connection to the natural world.

Drawing and painting allows learning more and connecting with nature on a deeper level. When people discovered the world of journaling, there is a natural progression to begin keeping a traditional nature journal. Having the chance to show to others the wonders of engaging fully with the world around us may widen those connections and spread the joy that nature and art have to offer us. There's an endless supply of wonder and fascination in the natural world.

2.1. The importance of Field Experiences – Understanding the Natural World

Wildlife conservation is the preservation and protection of animals, plants, and their habitats. By conserving wildlife, we're ensuring that future generations can enjoy our natural world and the incredible species that live within it. To help protect wildlife, it's important to understand how species interact within their ecosystems, and how they're affected by environmental and human influences.

Do experiences with nature, from wilderness backpacking to plants, to a wetland lesson on amphibian promote learning and connectedness with the natural world? Until recently, claims outstripped evidence on this question. But the field has matured, not only substantiating previously unwarranted claims but deepening our understanding of the cause-and-effect relationship between nature and learning. Hundreds of studies now bear on this question, and converging evidence strongly suggests that experiences of nature boost learning, personal development, and environmental stewardship (Ming et al. 2019).

Understanding ecological systems as they occur in the world is core to the discipline of ecology. Thus, field experiences provide valuable disciplinary training for prospective ecologists and natural resource science professionals (Klemow et al. 2019). Learning that occurs in a field setting can be a powerful experience that promotes truly connecting with nature, skill development and conceptual understanding, enhances environmental literacy, and instills social responsibility and a global mindset for new generations of scientists (Davis et al. 2012, Gretzel et al. 2014, Fleischner et al. 2017, Halliwell et al. 2020). Given the exceptional impacts of field learning, many university ecology and natural resource programs encourage or require a field experience at the undergraduate

level but also among all in general.

According to Morales et al. 2020, field experiences generally facilitate learning that is immersive and sustained, structure social interactions that build students' sense of agency, and promote development of specialized skills and content knowledge (Billick & Price 2010, Jolley et al. 2018, Halliwell & Bowser 2019). Student interest and motivation are engaged by aspects of the environment called out by the curriculum as well as by those that generate contextual interest for individual students. Learning is situated in the authentic practice of meaningful interactions with the environment and can create attachment to place (Jolley et al. 2018), strong connections to their cohort (Haywood et al. 2016), and feel part of something larger.

Environmental thinkers and educators have argued for the importance of celebrating our connectedness to nature, or the perception of being part of, rather than separate from, the natural world. Environmental education does not automatically lead to connectedness. However, if woven into the goals and approach of teaching, connectedness to nature can indeed be fostered in higher education and schools. This is a promising result for those working towards a sustainable future (Hadzigeorgiou, 1997).

Knowledge acquisition does not have a direct correlation with pro-environmental behavior change. However, when we foster connectedness with nature focusing on exposing people to the wonders of natural world, results can be more successfully than rather simple knowledge acquisition.

Instead of taking exams and writing papers, in a non-traditional biology or ecology practice it may be interesting to focus on reflection activities such as journaling, observations of natural areas, and experiential learning.

An essential component of nature relatedness is an internalized identification with nature, such that nature is viewed not as an external object but as part of the self. Indeed, one definition of connectedness to nature is the extent to which an individual's self-identity overlaps with nature (Schultz, 2002).

When there is a personal connection to nature, it is especially important for working towards a more sustainable future, because those who view nature as part of themselves are less likely to harm it (Duffy & Verges 2010).

Environmental education that does not intentionally seek connectedness as an objective is unlikely to manifest connectedness as an outcome. This is where the tradition of transformative learning (Mezirow, 2000, O'Sullivan, 2002, Taylor & Cranton, 2012) might play an essential role for environmental education seeking to develop connectedness. Transformative learning emphasizes the role of learning as self-transformation, rather than simply knowledge acquisition. Deliberately inviting learners to transform their understanding of themselves and their place in the world, specifically their relationship with the natural world, seems to be an integral part of increasing their connectedness to nature (Laukenau, 2018).

Observation and concentration are mental characteristics that vary greatly between individuals. Using the senses to their fullest capacity requires paying close attention to detail. Observation and concentration can be trained and by doing it in a natural environment it allows us to understand how nature solves "problems" based on evolutionary and adaptive processes of almost over 3 billion years. As you learn to develop skills in observing nature in a detailed way, you will also develop a relationship and respect for the natural environment and its lessons. This is indeed the principle of the science of sustainability, biomimicry. This frequent nature journaling practice engages us with the world around us in a way we usually don't pay attention to. Whenever you visit a new place, expand on how you connect with that place, through writing, photography, drawing, or even a simple meditative ritual. Nature is a model of inspiration and efficiency and shares lessons that provide us with key principles of resilience, adaptation, and success. Although surrounded by a resilient and regenerative natural environment, we forget to significantly implement the principles of nature in our projects and often revert them into models that we can inspire and emulate. Without a well-trained

capacity for observation, abstraction and concentration, the discovery of these successful natural processes is not perceptible to us. In a landscape with colorful transformations in autumn, it is interesting to observe and understand how "life" prepares itself for the long winter, releasing seeds in the wind to sprout in spring, which in turn, feed and protect in a soil covered with litter. Spending time looking outside helps us feel more connected to the places we live. We can begin to understand what makes this place ours, characterized by the presence of organisms and the way they respond to the environment in which they are inserted, the deepest patterns that reflect the true genius of nature. The observation and concentration training also ends up becoming a meditative path in which one evolves in a method that is inspired by the species, the habitats, and their dynamics. Observation and concentration training using the natural environment can be practiced repeatedly, individually, in a group and can be used at all ages, especially with the monitoring of parents or educators, in the case of children and young people.

We are part of nature. The worldview, values, and structure of everyday life in modern Western civilization attempt to obfuscate this connection, to the detriment of our individual and collective well-being. Awaken learners to their connectedness to nature, with a nature-focused worldview, and perhaps an experience that fosters comfort with nature can be trained. Environmental education that does not specifically address connection to nature is unlikely to develop it. This is an informative result for environmental scholars, as well as an inspiring one. The path to a sustainable future is detailed and not easy to achieve, environmental awareness that fosters connectedness to nature can positively contribute to this journey.

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II (INTER)NATIONAL BIOMIMICRY WEEKEND
Esadapress editorial
Granada, 5-7 November, 2021

SHARING THE STATE OF NATURE-INSPIRED INNOVATION IN THE UK

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Keywords: Nature-Inspired Innovation; Entrepreneurship; Technology Transfer; Technology Readiness Level

Abstract. *"The sooner people stop thinking about biology and start thinking about the nature of the problem, the sooner people will understand nature-inspired innovation. It's a matter of thinking more at the system's level" - Prof Julian Vincent.*

In this panel discussion, the founder of Biomimicry Innovation Lab, Richard James MacCowan, design researcher Yuning Chen and Sriram Nadathur, CEO of Nadathur Group, shared their insights into the academic, funding and industry landscape of nature-inspired innovation in the UK. How a solution-driven approach accelerates translating principles, we abstracted from nature into real-world impact. The talk was based on their extensive year-long research, data analytics, and interviews with academics, industry professionals, and investors worldwide.

1. INTRODUCTION

1.1 Objectives

This panel discussion aims to communicate insights from the latest research conducted by the Biomimicry Innovation Lab and Nadathur Group in their report, The State of Nature-inspired Innovation in the UK. In addition, the report aims to encourage discussions around the critical enabling factors in the innovation ecosystem around the field, such as early-stage collaborations between researchers and industry, funding policies and connectivity between stakeholders. Finally, it serves as a call to action in the field, such as strengthening synergetic collaboration and establishing common languages from different actors' perspectives.

Panelists:

- **Richard James MacCowan:** Founder and Biofuturist of Biomimicry Innovation Lab. Richard is an award-winning multi-disciplinary designer and works worldwide on urbanism, manufacturing, and agricultural projects. In addition, he has a background in international real estate investment and development and sustainable design, combining this with behavioural science and bio-inspired design. Richard is also the founder of the non-profit Biomimicry UK and an

equine technology startup, Smart Stable Limited. He combines this with extensive research development with international collaborators via the Design Society, ISO Standards in Biomimetics, Royal Society of the Arts, and the Bessemer Society.

- **Yuning Chen:** A design researcher with a background in environmental science. Yuning recently graduated from Innovation Design Engineering at Royal College of Art and Imperial College London. Her research interest mainly lies in the intersection of biology, informatics and design. Yuning has exhibited her work at the Dutch Design Week, Milan Design Week, London Design Biennale, and STARTS Festival.
- **Sriram Nadathur:** Entrepreneur, an angel investor, a philanthropist, and co-head of the Nadathur Group. He is responsible for the group's investments in Life Sciences, Health, Cleantech, Nature-inspired innovation, and Circular economy/sustainability. He is a biomimic, an engineer, and a business person based on educational degrees. Most importantly, he is a dreamer and a catalyst in helping make the world a better place by merging the heart (people, nature, and planet) and the mind (deep tech, innovation and startups). He recently finished his training in Biomimicry 3.8.

1.2 Background

1.2.1 Definitions

During the research, we identified groups of related terminologies. They are as follows: Bioinspired (bioinspired, bio-inspired, biologically inspired, biological inspiration); Nature-inspired (nature-inspired, nature inspired); biomimicry; biomimetic; and bionic; and ecomimicry.

In the panel discussion as well as the report (Biomimicry Innovation Lab and Nadathur Group, 2021), we use the concept of Nature-Inspired Innovation to sum up relevant practices and methods and define it based on the commonalities across all the studied cases - the act of applying mechanisms derived from natural processes into creating innovative solutions.

1.2.2 Trends and Opportunities in Nature-Inspired Innovation

Inspired by a solution-driven approach, we started market research looking into the state of nature-inspired innovation in the UK, where we spotted the significant gap between theory and technological transfer. We found many ongoing ideas and research with significant potentials in the field with a lack of commercialization to translate them into real-world impact.

Despite the growing trend in nature-inspired innovation, we are only translating around 12% (Vincent et al., 2006) of the natural processes into human technologies. This is mainly due to our limited ways to abstract models from natural phenomena and the inherent systematic differences between artificial systems and natural systems such as material chemistry, lifecycle, and manufacturing. Nowadays, with more advanced technologies to model natural processes and a collective momentum towards a more regenerative and circular system, we can collaborate with nature in unprecedented depth and complexity.

In the following sections, this paper synthesizes the discussion around opportunities and challenges in Nature-Inspired Innovation from three angles - academic, industry and finance and concludes with a list of future strategies towards a streamlined and well-connected innovation ecosystem.

2. RESEARCH LANDSCAPE

2.1. Overview

During the discussion, the panelists mapped out the broad scope and opportunities of Nature-Inspired Innovation across different fields such as computation, materials science, and biomedical research.

The conversation also highlighted the common challenges the research process faces in Nature-Inspired Innovation due to its developmental processes such as time scales, experiment equipment requirements, and funding gaps during the scaling-up process.

2.2 The Scope of Research in Nature-Inspired Innovation

Based on our extensive sampling of nature-inspired innovation research in the UK, we identified over 1500 researchers and circa 125 labs applying the principles of nature-inspired innovation in their fields. The research spectrum spans materials science, biomanufacturing, neuroscience, biomedical engineering to computation, physics, and architecture. Furthermore, the growing momentum of nature-inspired research has started to extend from mainstream research clusters such as the Russell Group and N8 Research Partnership to broader research networks such as the Million+, University Alliance and GuildHE.

2.3 Motivations and Challenges in Knowledge Transfer

2.3.1 Research and knowledge transfer

More than half of the survey participants expressed an interest in commercializing their work. Potential investors approached around 50% of them to collaborate. However, despite the significant interest in translating research into real-world solutions, many participants consider it a complex challenge. The intellectual property negotiations between researchers and their universities, high administrative costs and bureaucratic complexity of the process all add to the friction when they are trying to take their initiative forward.

2.3.2 Moving Forward

In order to effectively collaborate with industry partners and include a solution-oriented perspective in the research development process, we must train future generations of researchers with a business development vision.

Based on survey results, doctoral researchers working across academia and industry would benefit most from entrepreneurial support. Unfortunately, these individuals often lack consistent mentorship due to their early career status, which hampers them in developing sustainable practice in nature-inspired innovation as they continue towards graduation or doctorate level studies with 12-18 months left before completing one's dissertation proposal.

Furthermore, the alignment between research and the UK National Innovation Strategy (Department for Business, Energy & Industrial Strategy, 2021) should be more substantial on a systems level. Via connected networks and holistic funding schemes that recognize the characteristics of nature-inspired development cycles would enable a more effective knowledge transfer process.

3. INDUSTRIAL LANDSCAPE

3.1. Overview

In terms of the industry landscape, the panel discussion focused on translating current research into industrial practice through strengthening early-stage partnerships and connections between researchers and industry.

As mentioned in the research landscape session, this mapped out the relevant developing technologies in the current nature-inspired research repositories and identified a vast space for impactful innovation. A comprehensive database was built with research archives related to Advanced Materials and Manufacturing; AI, Digital and Advanced Computing; Bioinformatics and Genomics; Engineering Biology; Electronics, Photonics and Quantum; Energy and Environment and Technologies; Robotics and Smart Machines.

3.2. Opportunities From Market and Governmental Policies

Apart from sharing potential research that aligns with the UK Innovation Strategy, the panelists also provided a comprehensive analysis of the key initiatives that are driving the market need, such as sustainability via the UN Sustainable Development Goals (United Nations, 2015), the four pillars of technological innovation (BEIS, 2021a) and how relevant research can contribute to the vision of positive climate innovations.

The UK's Innovation Strategy opens up a growing area for technological innovations that protect natural systems and promote environmental sustainability. However, to overcome funding challenges at different stages of development in this field, it will be crucial to form strategic alignments with government policies and resources.

With the growing momentum in climate technology research in nature-inspired innovation, it is crucial to encourage more early-stage development among industry, finance, and academia to cross-pollinate and situate the research in the most impactful application direction.

3.3. Overview

Based on the previous sampled database of researchers from across the United Kingdom, 350+ funding streams ranging from research councils, foundations, charities and philanthropic organizations, and industry, the panelists brought up some critical issues in the funding landscape of nature-inspired innovation such as the design of the funding policy, the funding gaps and connectivity between stakeholders.

3.4. Challenges and Opportunities

During the discussion, it was widely acknowledged that current relevant funding policies are not supporting the full potential of the UK's research in nature-inspired technology. This is also backed by the survey result and funding data collected by the previous study. According to the data, a valley of death/funding gap was identified during the development of Technology Readiness Levels 4-5 (Horizon 2020, 2014).

The UK is leading Europe's Tech for Good (Aït-Si-Selmi et al., 2020) ecosystem with over 490 Tech for Good companies tackling many challenges such as Job Security, Material Living Standards and Environmental Sustainability. Further, there is also a significant growth of investment in the UK in cleantech, renewable energy, climate tech and circular systems, according to Pitchbook (2021) data, which are highly relevant application directions of nature-inspired innovation.

A revised funding scheme is crucial to channel the increasing resources into highly innovative research. It should include critical characteristics such as a more open focus to accept interdisciplinary initiatives, a tailored distribution of research across different stages and a deeper understanding of the nature of cleantech developmental processes.

4. CONCLUSIONS AND CALL TO ACTION

During this panel discussion, we shared our first step in understanding the research community's needs to enable greater collaboration with industry and focus on the commercialization of ideas within the nature-inspired innovation space. Our research has identified a wide variety of research topics at different stages of maturity across the breadth and depth within the United Kingdom. However, what is apparent is the need to appeal to a broader range of funding sources and identify the potential industrial applications for many of these proposed technologies. The main points are concluded as follows:

- **Stronger links between academia and industry:** Bringing stakeholders into the beginning of the research process can help align the research towards a more solution-driven direction to foster a closer partnership between researchers and industry. In addition to that, they will create roadmaps tailored for different types of projects developed by these partnerships.
  - **A)** Creating common languages is crucial in order to achieve success during partnerships.
  - **B)** Early-stage collaboration is vital. It provides the most extensive freedom for businesses and research to coevolve into a mutualistic partnership.
- **More effective funding policies:** Interdisciplinary research can be challenging to fund, especially when it straddles boundaries between different disciplines. However, there are ways that this difficulty could potentially become a competitive advantage for institutions looking at their portfolio of projects from a holistic perspective rather than just focusing on individual scholarships or grant applications alone. Therefore, we advocate creating more effective policies with a broader scope by identifying overlap in interests across fields.
- **Entrepreneurial training for academics:** It is crucial to foster entrepreneurial visions and skills among academic communities to accelerate their knowledge translation into applications. One strategy is to communicate research output in ways that appeal specifically and uniquely to gain traction from different stakeholders - for example, by collaborating or networking outside one's discipline; effectively tailoring presentations based on whom the audiences might benefit most from this new invention/innovation.

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II (INTER)NATIONAL BIOMIMICRY WEEKEND
Esadapress editorial
Granada, 5-7 November 2021

IMPROVING OUR POWERS OF OBSERVATION THROUGH DRAWING

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Keywords: Perception; Nature; Observation; Drawing; Inspiration: Journaling

Abstract. *An approach to hands-on workshops in which participants learned the key steps in how to create a nature diary. Participants learned how to combine drawings and texts, connect closely with nature, how to train the perception of nature through their senses, and writing about what they saw. The act of finding the names of species, the use of apps, connecting with naturalists and guides to look for organism identification further enhance learning and breakdown the barriers to getting started. The results of this experiential workshop were that people lost their inhibitions about being able to draw, to become a naturalist, if only for a few hours. Participants gained the confidence to make their own nature diary.*

1. INTRODUCTION

Understanding how to see the world differently, especially the natural world is both a gift as well as a necessity in our current times. We take for granted so much of the basics of life without giving thought to where the underpinnings of all our resources practically come from. We know that as humans become ever more disconnected from the natural world, we must find new ways to understand and then be inspired by the magic of even the tiniest of details of how life works. Also, learning how to see the intricacies of nature in new ways provides a foundation for biomimicry and nature inspired innovation which in turn, can support new kinds of creativity and the associated innovative solutions. Nature's functions are the keys to a bio-inspired practice and with guided, hands-on observation techniques participants were provided with simple to use tools as the building blocks to becoming a competent observer and then illustrator. The goal of the workshop was to support the creation of a nature diary with drawings and texts, connecting closely with nature, training the perception of nature through senses, allowing the participants to first of all see and then to communicate the functions of nature.

2. METHODS FOR NATURE JOURNALING WORKSHOP

In the workshop, participants dedicated their full attention to observing and drawing in order to reconnect with the natural world. Previous artistic experience was not necessary as participants were guided through relaxed observational drawing activities in order to absorb the detail and visual complexity of provided organisms.

In addition, participants learned about how to find the names of species through apps and guides to look for their scientific identification in order that they would understand how to make their own nature diary.

To be a naturalist today is to find a balance between embracing modern technology and cultivating a direct and contemplative connection with nature.

Nature journaling is a path into the exploration of the natural world around us, and into our personal connection with it. Spending time observing and responding to what we see using a journal, is an easy way to establish contact with nature.

Nature journaling helps to develop sense of a place and our role in that place. In today´s world, people are transient, moving often without much thought or knowledge about the actual land where they live, how it was formed, which species inhabit the region, who lived there in previous times.

2.1. Getting started with nature journaling

• To keep in mind. As we intensify our observation of natural objects and events we may well encounter one of the dangers of such a practice by focusing too narrowly on the object, missing what surrounds it. The best way to compensate for this is to develop the ability to perform intermittent focus and then refocus our attention to the middle distance surrounding the object, and with which it may be quietly interacting. After a few seconds at this level taking even a broader perspective of the general scene that includes the object and its near surroundings further enhances the practice. Refocusing on the object for a few seconds and repeat observing large circles of influence in this way, we may observe and then understand a much broader view of an ecosystem.

• **Being inspired.** Starting with a leaf or tree rubbings, is always inspirational, using poetry, measurements, or charts, teach us to have an idea of scale and how colours mix. Looking for patterns, quotes, nature stamps, making lists of birds, insects, or flowers we have observed deepens our experience.

• **Recording sit spot seasons.** Register what we see along the year, sit in the same spot at least once during each season. Journaling might well be thought as a form of journeying through the seasons outdoors as well as through our own inner seasons. As we journey through life our journals become a record of where we have been, what we have seen and attended, to what we have felt as we interacted with the natural world.

• **Recording animal tracks.** We can ask questions like: where are they going? Who do they belong to, what does this remind me of? Why? Wonder will produce answers on our own without the help of a field guide or a phone. Writing them down and checking later is an especially useful procedure to start learning about a species.

• **Cultivating curiosity. Becoming a good naturalist is mostly a matter of being attentive.** That is a habit that we can develop, but it takes practice. Why not try to learn something about the natural world every time we take a walk outside?

• **Learning the names and taxonomy of plants and animals around us.** Conversations are much more interesting and useful when we all use the precise names of what we are talking about and this is particularly true of natural history, starting with plants and animals that we encounter every day. Though one may just use species common names, at least initially, it is possible to learn much more by glancing at scientific names.

• **Becoming familiar with the basic ecology of plants and animals.** This means to learn as much as possible about what kind of habitat they prefer, when they breed, what they eat, who or what eats them, how long they live. The more natural history knowledge is acquired, the more is learnt and understood.

• **Going on walks with knowledgeable naturalists and taking notes.** To take advantage of naturalist "teachers" whenever is possible.

• **Asking "how?" and "why?" questions.** Once we can identify a plant or animal, we should not stop there, cultivating curiosity with a purpose. Remembering a more fulfilling approach, one could follow Thoreau's advice "to know it by experience, and be able to give a true account of it."

• **Scrutinizing.** Touch, smell, listen and measure. Actual experiences lead to more enduring memories and a more profound comprehension of the natural world.

• **Analysing our observations.** The longer we continue our observations, the more valuable our records will become. And the more we ponder the resulting patterns, the more profound will be our understanding of nature.

• **Learning to truly observe.** Observation is at the heart of nature journaling. Observation deals with using all our senses and perceiving the reality of what they reveal. When we became attuned to the context of the objects we previously thought of as isolated. Discovering these connections takes a conscious effort to fully engage our senses and mind.

• **Overcoming fears of drawing.** Some people panic at the thought of making sketches in their journals. If we believe we cannot draw, now is the time to lay that fear aside. Everyone can draw at some degree of competency by simply making lines that correspond with what is observed. Whenever someone thinks they are good or bad at drawing is not the issue. No one is particularly good at anything unless they have practiced and add some instructions. In this workshop attendees were encouraged to try to express their observations the way they could. This is another way nature journaling offers to those drawing the natural world, a chance to grow personally and broaden our skills for living.

• **Where to draw.** Nature journaling can be done about anywhere, indoors, or out wherever there is something living we can begin to observe. Access to where we can begin honing our observational skills and developing a new sense of the place we call home as we sit amidst each of the spots asking ourselves what plants grow there? What trees? What things affect their growth? What insects can we find? How do we imagine a place looked 50 or 100 or 200 years ago? How has the plant and animal life changed over time?

3. CONCLUSIONS

Even those of us living in rural locations or visiting there often spend much of our time racing to and from, and forgetting to take to the time to just be and observe the world around us. Our beliefs and attitudes shape how we interact with the world, and impact our approach to learning from and with nature. In this workshop we explored some common issues and practiced some strategies to release the old patterns, and welcome more ease, joy and wonder into our nature journaling practice.

The attendees became more experienced at journal keeping in the context of the page they chose to make their compositions. Teaching how to look for connections and interactions as they were observing and writing or drawing, correlating what we have observed to other observations of the greater world around us.

The attendees became surprised about their abilities to register and comprehend natural forms. To be able to find a new way to understand nature and communicate those learnings. The experience provided confidence in new found skills and created a will to continue the practice of nature journaling.

Figure 1. Guidance for drawing tools

Figure 2. Guidance for using measures and descriptions to better understand what we are seeing

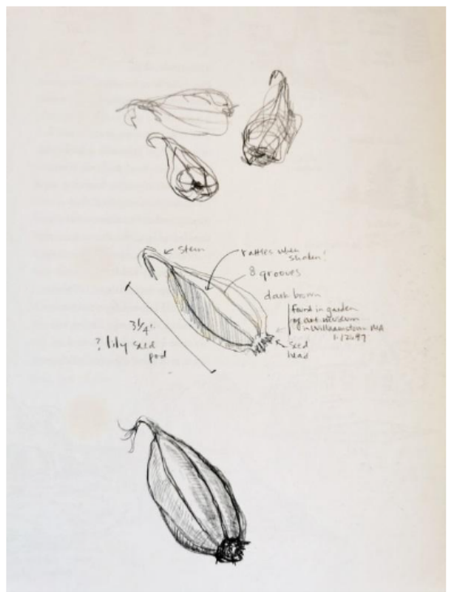

Figure 3. Drawing of Claudio Palomo

II (INTER)NATIONAL BIOMIMICRY WEEKEND
Esadapress editorial
Granada, 5-7 November, 2021

BIOMIMICRY – AN APPROACH TO ENGAGED SCIENCE AND SUSTAIBABILTY

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Keywords: Biomimicry, sustainability, science.

BRIEF DESCRIPTION

The article explores opportunities to integrate biomimicry into subject teaching, provide real-world contexts for the application of science, and demonstrate how biomimicry provides an engaging focus for science and sustainability.

Abstract. *In this article, biomimicry is discussed as an approach to nature-inspired learning. Specifically, we examine the potential for augmenting STEM subject delivery through a biomimicry approach. Biomimicry is introduced as a concept before looking to the practical application of biomimicry as a teaching approach. Subjects commonly taught in English schools are examined for their links to principles of biomimicry before providing the reader with a more detailed example of how a scheme of work might be adapted to make use of nature-inspired learning through biomimicry. An example of a resource is provided. We conclude with a detailed discussion of the methodology of teaching and delivery as well as a commentary on the pedagogical potential of this approach.*

1. INTRODUCTION

Through 3.8 billion years of evolution, the living world provides a rich source of inspiration for our own human endeavors to live in harmony with natural cycles and systems. While nature relies on experimentation, we can learn important lessons from the natural world at a time when human impact is degrading the Earth's ability to support us. For example, nature has already addressed some of the most pressing issues of our time: nature recycles waste efficiently, uses renewable power from the sun, is resilient to sudden changes, is adaptable over time to new conditions, and self regulates through feedback. What if we could use these operating principles found within nature to rethink how we live as humans? To flourish without damaging the natural ecosystems we depend upon for our survival.

This article draws on the European BioLearn project which developed biomimicry-based STEM programmes for students aged 11-15 in the UK, Netherland, Czech Republic, Slovakia,

and Hungary. It presents the opportunities biomimicry offers to enrich the teaching of science. These can be seen within biology as shown in table 1 below; further examples are provided throughout the article.

We offer this article as both an introduction to biomimicry and nature-inspired learning, as well as a springboard for thinking about implementing such approaches into STEM subject delivery. This article begins with a definition of biomimicry, as we make use of it in BioLearn, and then moves on to consider its application in science education and the opportunities it presents for the curriculum in England in particular. We provide an overview of how biomimicry supports various subject requirements commonly taught in schools and examine in detail the adaptation of a biology scheme of work to make use of these opportunities. The article then goes on to discuss the methodologies appropriate to working with a biomimicry approach before concluding with a commentary on the pedagogical potential behind biomimicry as a learning approach, as well as how it offers a touchstone for connecting learners with nature.

Table 1: Different examples of how biology has inspired technology

Source in nature	**Technological application**
Dermal denticles of shark skin	Swimsuit materials
Light capture and transfer processes in leaf chloroplasts	Inexpensive solar cells
Hitch-hiking seed (bur) design	Velcro fasteners
Internal artery wall function	Bioactive coronary stents
Gecko foot hairs	Dry adhesive applications
Kinematic configurations of a stick insect	Walking robots

WHAT IS BIOMIMICRY?

Biomimicry (meaning 'to copy life') takes us on a journey to discover the principles which makes nature a model for sustainability, a model which achieves dynamic balance, sustains the whole and provides the conditions for life. Biomimicry offers an opportunity to explore how these principles can help tackle some of the greatest challenges facing humanity today such as climate change and increasing levels of waste and pollution. And finally empowers students to creatively apply their new competences to discover solutions that work.

Biomimicry has been defined as 'learning from and then emulating natural forms, processes, and ecosystems to create more sustainable designs' (Baumeister, 2014). It does this based on three inter-twined values:

1. **Emulate** – observe nature closely and we can see how organisms use a vast array of strategies to provision their needs; these strategies are being emulated by many companies in product design. It occurs when we tackle human problems through the inspiration of nature and minimize our impact on the Earth.
2. **Reconnect** – learning from nature requires deep curiosity and observation, reconnecting to the natural world at a level beyond mere utilitarianism. It is about regaining the recognition that we are a part of nature and the relationship between humans and nature is essential for our survival.
3. **Ethos** – understanding how we are an integral part of nature, and how nature brings about balance and harmony, we choose how to apply biomimicry thinking with an ethos of care and empathy with all life. It signals the intention to proceed only in ways which work alongside natural balance.

When these values are taken together, biomimicry offers a different way of seeing nature; supports a shift in view of learning about nature to learning from nature. It explicitly places the natural world as a source of solutions to human challenges, providing a moral and practical reason for the conservation of

the natural world. It facilitates a deeper looking at the natural world, through which a sense of sacredness can emerge. These aspects of learning are more important now than ever, with increasing evidence of young people's disconnection from the natural world, and, at the same time, increased realisation of the multiple benefits which come with building relationships with the natural world. Providing this type of immersion into nature and building connection holds the potential to create pivotal moments in learners lives, and underpins health and wellbeing (Soga and Gaston, 2016; Wolsko and Lindberg, 2013).

Biomimicry principles can relatively easily be gleaned by observing nature (essential observation skills are developed) and asking questions (another key skill). Nine principles are commonly agreed upon and, when applied to addressing human challenges, offer excellent opportunities to develop Working Scientifically competences (see Biomimic Academy, 2020 for description - https://biomimicacademy.com/9-basic-principles-of-biomimicry/). Underpinned by the sciences, biomimicry also applies life-centred design and business modelling. This mixture of methods can be used to design products, services, processes, and whole systems. For example, take the principle 'nature recycles everything.' This can be observed in leaf litter. Although trees produce an abundance of leaves which are then shed, none create waste, and all are food to other parts of the ecosystem. To achieve this, nature builds everything using locally available sources of mainly carbon, hydrogen, and oxygen – trees are 99% carbon, hydrogen and oxygen which is mined from the air. How could industry emulate this principle to create products which also produce no toxic waste? The US company bioMASON is growing bricks for the building industry using bacteria to create the 'glue' which combine sand into a brick. This takes place at ambient temperature using locally sourced materials (Smith et al., 2015).

BIOMIMICRY WITHIN SCIENCE EDUCATION

Biomimicry naturally allies itself with the STEM curriculum and finds clear connection with subjects in the natural and physical sciences, yet also requires a cross-curricular mindset, calling for links to be made between often discreet subject areas. Many schools are now favouring this way of working and find that knowledge and skills are reinforced by a cross-curricular approach. By integrating biomimicry into a variety of subjects, students will naturally be able to find common ground between subjects.

Curriculum opportunities are only limited by imagination. Biology teaches us about how nutrients cycle in a woodland and can help us realise how technical nutrients could cycle in product design. Chemistry shows us how nature creates infinite shapes and forms using simple formulas which degrade back into harmless elements and compounds. Tellingly, nature uses only 28 of the 118 elements, and of those 28 it mainly uses carbon, hydrogen, and oxygen as building blocks. Physics demonstrates how forces can be harnessed to reduce energy use. Technology and engineering can use the science of nature to build new products, processes and systems which elegantly mirror nature's sustainability.

Table 2: examples from the Programmes of Study from the National Curriculum in England.

STEM Topics	**Biomimicry Examples**
Adaptation, Variation and Classification **(Bio)**	Finding natural solutions to problems and challenges faced by human society can be as straightforward as looking to how nature has adapted to its environment. Structural and behavioural adaptations can be mimicked in human designs – for example looking at the ingenious ways that desert-living creatures can maintain habitable temperatures by living underground or building self-cooling structures (see Termite mounds).
Biodiversity and Ecosystems **(Bio)**	At an ecosystem level, nature teachers us much about how to organise society and live as part of an interconnected web of life. This offers learning opportunities which go beyond simply looking at one organism – and instead prompts us to consider what it might mean to live in community and to occupy specialist niches without jeopardising the living system we rely on.

Life cycle assessment and recycling to assess environmental impacts associated with all the stages of a product's life **(Chem)**	Materials developed in nature use water as a solvent and are degradable back into elements (carbon, oxygen, hydrogen, etc). Man-made substances tend to rely on far more complex chemical structures which do not easily degrade back into the elements, often creating a long-term source of pollution. Applying a nature-inspired life-cycle to creating human products can lead us to exploring mussels to create water soluble glue, the refractive properties of butterfly wings to create colour rather than oil-based paint, and how coral produces cement at ambient temperature.
Cycles and Nutrients **(Bio)**; Lifecycle and Recyclin **(E/DT)**	The cycles which underpin life on earth, whether carbon, nutrient or water, are fundamental to the balance of give and take which is in continuous motion across all ecosystems. This topic once again makes us aware of the large, interconnected whole we are a part of on this planet. Offering much in the way of sustainability thinking, considering the ways in which nutrients are cycled and reused in an ecosystem presents opportunities to learn about circular economies, and new ways of thinking about commerce.
Photosynthesis **(Bio)**; Energy Sources **(DT)**	Energy and its uses are the centrepiece of life – and for much life on earth that energy comes from the sun. Understanding photosynthesis is a key piece of science which has allowed us to consider the function of food chains and population pyramids – but so too it has enabled humans to vision the possibility of producing clean abundant energy.
Materials, Forces and Properties **(DT/Phys)**	Nature is versatile, and it rarely produces waste. The materials deployed and produced by processes and organisms are honed over millennia and are fit for purpose. Looking at how nature produces flexible, hard, strong and light materials which enable the most incredible functions and offer inroads to thinking about overcoming the biggest design challenges. Looking at how Geckos stick to smooth surfaces has resulted in engineers creating new adhesives which work on structure rather than solvents; looking at bee's use of hexagons for storing honey in a hive has opened our eyes to strong and efficient use of materials for building.

To take one example and expand on it, we have worked with a biology teacher to consider how a scheme of work (SOW) might be adapted to involve biomimicry. While many teachers are faced with a degree of content-overload, it seems appropriate to see how a biomimicry approach might support the curriculum-based content already delivered. Comprising nine lessons, the 'variation, classification and ecology' SOW provided plenty of opportunities to work with biomimicry, although some lessons held more potential than others. In table 3 and the associated worksheet (fig.1) we demonstrate how one lesson (variation and classification) was able to be expanded and adapted to make use of biomimicry learning.

It is necessary to emphasise that the biomimicry activities and resources discussed in this example did not replace those already used by teachers (although some reorganising is involved), rather they supported the delivery of the lesson. For example, in table 3 it is noted in the 'standard' resources' column that the teacher would provide the students with some time to explore outdoors to make use of a dichotomous key and understand variation and classification in the natural world. The next step for us when considering a biomimicry approach was to think about what students might be able to learn from this experience, and how they might be able to observe the natural world to learn about how nature solves multiple challenges. In this example, the students focus on trees in the school grounds, and – while beginning with identification – this leads to deeper questions about how the tree has evolved to provide strength, protection, energy etc. Students are led into an enquiry which helps them to see trees as a source of inspiration for human based problem-solving, and steps beyond a simple identification task.

Table 3: Excerpt of a Scheme of work for biology

Learning Outcomes Students should be able to:	**Activities & Resources** (standard lesson)	**BioLearn Activities** (to support standard lesson resources)
• Identify differences between living & non-living things (Movement, Respiration, Sensitivity, Growth, Reproduction, Excretion, Nutrition – MRS GREN) • Understand that individual members of a species may vary and that these variations may be inherited or caused by environmental differences. • Observe that members of a species have features in common. • Use keys to sort organisms into groups by common features. • Appreciate that there are different ways of classifying living things (e.g. by colour, habitat, initial letter, similar features). • Understand that scientific classification is a worldwide labelling system (which uses similarity of features to place organisms in groups).	• Draw comparison between living and non-living things to show how we classify life and objects. Go outside and use a dichotomous key. • How do we begin by identifying organisms? What features should we look for? • DVD 27/1 Life on Earth Episodes 2, 3 & 4 • Exercise in text book – focus on history of classification and how species have characteristics in common.	Kick-off question: How do trees inspire designers? Could do a quick 5-minute paired brainstorm or leave it hanging. *Provide a set of images of inventions/designs inspired by trees. Ask students what inspired each of these designs? (we'll return to these examples at the end of the lesson)* **ACTIVITY:** To link with the existing outdoor ID activity – make use of Tree ID challenge sheet (see fig.1) in association with a tree ID guide. Students gain experience using a dichotomous key and thinking about classification whilst considering: • What characteristics give this tree strength? • What characteristics provide protection? • What characteristics provide energy? • How do these characteristics provide functions which enable to tree to thrive? • How can we use features to identify and classify the tree? • How can a tree help us to understand human design challenges? Later, at the end of the lesson this can be used to consider how trees have inspired human design. The following question could also be used, if appropriate: How do trees MRS GREN? How do non-living things MRS GREN? Can non-living things mimic MRS GREN (show the tree: buildings slide)?

TREES AS INSPIRATION

TASK 1: Working in pairs use your Tree ID guide to find and identify a tree nearby. What species of tree have you identified?
TASK 2: Look closely at the tree. What features allow you to identify this tree? What makes it different to other trees nearby? Consider the following questions, and write down a response to each:

You may wish to label the picture of the tree on this worksheet with your responses instead:

1. What characteristics give this tree strength?
2. What characteristics provide protection?
3. What characteristics provide energy?
4. How do these characteristics enable to tree to thrive?
5. How can we use features to identify and classify the tree?
6. How can a tree help us to understand human design challenges?

Label the diagram of the tree below with some of your responses

BIOMIMICRY AS A LEARNING METHODOLOGY

The principles of biomimicry correlate closely to those of inquiry-based science learning and design-based learning (Pedaste et al., 2015). These are teaching methods that stimulate students to actively investigate and discover the world around them. The curiosity that students naturally have plays a key role in these methods.

The biomimicry design spiral (BDS) (see figure 2) developed by Carl Hastrich provides teachers and students with handles to start designing a solution to solve a given challenge. The BDS is often used as a method for problem solving and designing.

There is a reason this tool is shaped in the form of a spiral. The spiral geometry can be found everywhere in nature. Even though we refer to many processes in nature as cycles, they are in a sense all spirals in time, the endpoint is usually not the same as the starting point. Rossin (2010) notes that the design spiral with its associated 'feedback loops' is more functional as a problem solving tool than its linear contemporaries "because [it] is a reiterative process, after it resolves one challenge and evaluates how it compares to Life's Principles, most likely another problem appears, and the process begins again" (Rossin, 2010: p.562).

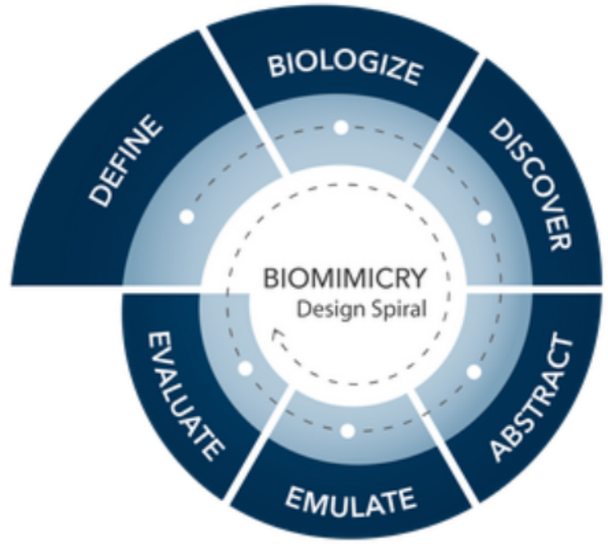

figure 1: biomimicry design spiral, biomimicry institute (www.biomimicry.org).

Going through the different steps in the BDS ultimately ends up with a design or solution. However, comparing the steps found in the BDS with steps found in inquiry-based science education (IBSE), there are a quite a few similarities based on the 5-E model (see https://bscs.org/bscs-5e-instructional-model/).

While biomimicry is often used primarily as a design method, because of its resemblance in steps with learning methodologies such as IBSE, it can very well be used as a learning method. The most important steps in IBSE are also present in the Biomimicry Design Spiral, and for that reason this method can be used to ultimately achieve the same improvement in the learning process IBSE has. When biomimicry is used as a learning method it could even add aspects to the learning process that IBSE does not hold. Biomimicry teaches students the value of nature for us as humans, but also the value of nature in itself. As today's students are the leaders of the future, it is important to help them see and experience the beauty of nature, and create gratitude and an ardent desire to protect the genius that surrounds us. On top of improving the learning process itself, biomimicry can teach students to create products, processes and policies that are well-adapted to life on earth over the long term. The eventual aim is, therefore, to create an attitude in students that will motivate them to preserve nature on the planet.

BIOMIMICRY PEDAGOGY – MORE THAN SCIENCE… (A HYPOTHESIS)

From a pedagogical point of view, biomimicry offers plenty of rich and engaging approaches to learning as briefly outlined in the previous section. The notion of examining and asking questions of nature in order to address a challenge offers opportunities for problem or project-based learning.

The invitation to get hands-on with nature, explore concepts in-situ and use the senses to consider where answers might exist creates opportunities to take learning outside, through experiential activity (Beard and Wilson, 2002; Pedaste et al., 2015). Much of the activity on offer within the BioLearn materials can be adapted to different settings, to suit a variety of pedagogies and learner needs, and align themselves to learning methodologies such as problem-based and experiential learning.

As the three values briefly laid out in the 'What is biomimicry?' section suggest, biomimicry is not simply taking ideas from nature to create better products to serve human needs. It goes further, and necessitates a deep observation of how nature works, the inter-relationships between organisms and their environment, and an innate sensing of nature's cycles. In this way, biomimicry offers a method to rethink our relationship with nature, rediscovering our place within the natural world, finding balance, harmony, and renewal. In this sense, biomimicry can be far more than a neat science solution; it can be used to engage learners deeply with the natural world. In this way, biomimicry can itself become an 'natural pedagogy' rather than simply tool of science.

CONCLUSION

We can see that looking to nature for inspiration goes beyond simply copying and presents learners with opportunities to enrich and broaden their learning beyond facts and into a new relationship with the natural world. At its heart, this approach is about taking notice, and being curious – a cornerstone of nature connection, and the foundation of recent work examining the propensity of nature-based learning to contribute to wellbeing and pro-environmental behaviours (Lumber et al., 2017; Pritchard et al., 2019). We need to be careful to understand that biomimicry is not an approach of 'going back to nature' nor does it suggest that nature is always right. Rather, biomimicry offers principles based on how nature operates sustainably that we can learn from. Too often environmentalism suggests: technology = bad and nature = good. Biomimicry offers a more balanced approach, showing that technology can be and is hugely beneficial, and if designed based on natural principles can also ensure it leaves no toxic legacy – a goal still some way off.

Biomimicry offers multiple points into the natural world. It can be entered from an intrinsic point of view: seeing the inherent worth of all beings regardless of their value to humans, broadening out into seeing how nature works and applying nature's principles to address human needs. Or it can be entered from the perspective of a more instrumental science challenge, exploring nature to see how organisms have solved similar challenges; or even stripped back to look at the properties of materials and structures and how they can be applied in a variety of situations. In this sense, biomimicry can appeal to a wide range of people regardless of their current views of nature.

As is being demonstrated in the BioLearn project, biomimicry provides a coherent fit across science disciplines, offering content and application within a meaningful context. Pedagogically, biomimicry is attractive because it supports a move towards inquiry-based learning. It is also satisfying for teachers wishing to make use of the outdoor environment and reconnect their learners with nature. It can be seen as a unifying theme which links subject content with issues students both care about and will be important for their careers in the future; one study estimates that biomimicry innovation-related employment opportunities are producing over 1.5 million jobs in the United States alone (Fermanian Business & Economic Institute, 2013).

Biomimicry can help us see beyond the usual events and patterns of our daily lives. It can suspend our usual way of seeing nature and offers a new mental model to reshape our relationship as a part of nature. Biomimicry provides inspiration to go beyond simply copying nature and presents learners with opportunities to enrich and broaden their learning beyond facts and into a new relationship with the natural world.

About the BioLearn Project: The BioLearn project helps young people think about what sort of future they would like to live in. How can they contribute to that future? Can it become reality?

BioLearn challenges traditional assumptions about how things are made and how entire economies are managed. BioLearn is about re-thinking the future, a future that is already happening because many companies are already fascinated by nature and are innovative enough to create 'bio-inspired' design.

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2021