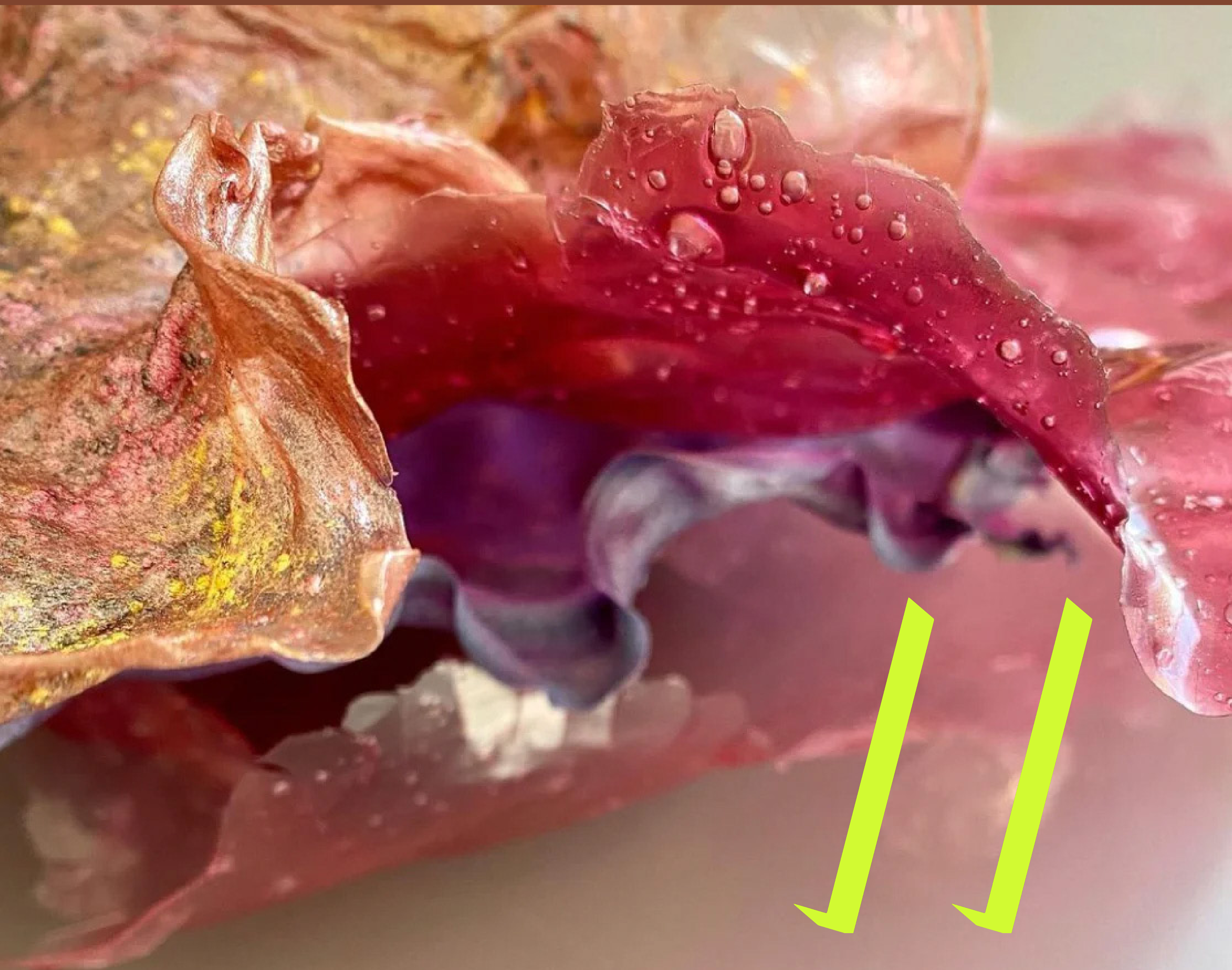
BEYØND ØBJECTS //

MATERIALITY AT THE EDGE ØF MAKING

2024 Volume 9



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Making Futures Journal

Volume 9

Beyond Objects:
Materiality at the Edge of Making

2024

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Foreword

This volume represents the ideas and explorations of the 8th gathering Making Futures™ conference on the relationship between craft, sustainability and new technologies, convened by the University since 2009. Bringing together a host of international artists, designers, scholars and cultural leaders, it aims to lead a critical conversation on both traditional and innovative materially-led creative practice. The 2024 conference brought together approximately 98 speakers from around the world, including those from Australia, Portugal, Peru, France, Japan, India, Columbia, Canada, Sweden and the United States, as well as participants and speakers from across the United Kingdom. This demonstrates the collective passion for craft and the importance of sharing knowledge and understanding of the material world through creative practice and practice-led research.

Making Futures™ has been an early pioneer in recognising the link between small-scale artisanal and place-based craft production and the need to find a more equitable and environmentally responsible way of living with each other and our planet.[1] Previous iterations of the conference have focused on identifying the ways in which new distributive manufacturing protocols and networked technologies provide an opportunity for localised skills and indigenous knowledge to be shared more broadly, and identified a then emergent axis between vernacular, regional creative practices and sustainability—our now common awareness of the urgency around changing our contemporary habits of consumption and accumulation. The international aspect of Making Futures is an important part of its knowledge sharing, and many previous conferences made vital links between the global north, western and European nations, the global south, Southeast Asia, Asia and many other regions. As this axis of knowledge has become more refined over the last few years through networked-based cultural forms such as distributed design, community craft cooperatives, the platform economy, citizen science, green craft toolkits and the internet of things, among others, Making Futures has provided a space for speculation and debate on the impact of these practices on the meaning of what we make. It has challenged the notion of globalisation as the inevitable arc of economic and cultural development, and has provided alternative narratives for how our vast information infrastructure might equally extend our imagination for how this connected world can foster a greater sense of local collective purpose.

[1] 'This is an ongoing programme that aims to contribute to a more comprehensive and sector-wide understanding of the contemporary crafts in relation to environmental and social equity issues, and especially in the way that these factors impart new ideological purpose to the idea of craft.', M. Ferris, Introduction to the first Making Futures conference 2009.

Acknowledgements

An event of the size and scope of the 2024 Making Futures conference, which is documented through this edited volume, could not be achieved without the committed work and brilliance of many people. There were also a number of featured projects and programmes developed with partners, colleagues and supporters as a component of the 2024 conference that must be recognised.

One most significant project was a month-long artisan-in-residence programme co-developed with the British Council in partnership with the Delhi Crafts Council and Arts University Plymouth, featuring master weaver Shamji Vankar from the Kutch region of northern India. An expert in traditional indigo dyeing and loom weaving processes perfected over many generations, Shamji worked with our BA Textile Course in an exchange of knowledge and techniques that taught us how to optimise place-based dyeing processes, particularly in the context of our Natural Dye Lab. I would like to thank the British Council and Delhi Crafts Council for their support of the residency as well as for their long support of Making Futures.

In addition to this artisan-in-residence programme, there was a roundtable discussion celebrating the 10-year anniversary of our Fab Lab Plymouth, with a review of the meaningful case studies and impactful innovations we have developed as the first Fab City in the UK to be part of the Fab City Global Initiative. This anniversary relaunches the Fab Lab Plymouth as the expanded Fab Lab South West.

To guide our discussions and to help frame the possibilities and challenges set by the conference, Making Futures 2024 was fortunate to have three accomplished keynote speakers:

Sherry Lassiter, co-founder of MIT's FabLab network, and CEO of the Fab Foundation, joined us to share her views and experience of the power of new technologies to shape not only creative practice and manufacture, but to shape our relationship to knowledge, where access to emerging technical skills and increased digital literacy transform communities. Sherry's work has had a lasting and far reaching impact on the ways in which technical knowledge and expertise is distributed across cultures and nations, ensuring that this knowledge is an accessible, transformative resource for all.

The conference also welcomed entrepreneur and designer Elissa Brunato, Founder and CEO of Radiant Matter, a London-based start-up company which is revolutionising the small in size but not insignificant environmental impact of the metallic sequin used in fashion around the world and consequently lodged in our water supply and landfill. Elissa has worked closely with physicists and materials engineers to develop a new Biosequin made of structured cellulose through a molecular design that transforms a naturally clear polymer into a brilliant, iridescent surface. Her iridescent Biosequins demonstrate that biologically derived and ecologically resilient design products can be beautiful, colourful and, most recently through a partnership with designer Stella McCartney, a viable alternative to fast fashion.

The final keynote was delivered by Professor of Materials and Society, Mark Miodownik, from University College London who is also co-founder of UCL's Institute of Making. Prof Miodownik's deep knowledge of materials and their impact on our society and social relationships provides artists and designers with the opportunity to return to the very building blocks of the natural world with new eyes. His work provides us with a pathway to reimagine the broader role of creativity in designing a world that is less alienated from the phenomenal

forces around us. This is his second appearance as a keynote speaker at Making Futures, where he spoke in 2017, demonstrating his lasting influence on the project and the ambitions of this research platform.

We are grateful for the willingness and enthusiasm expressed by each of the keynote speakers to frame the discussions held over the three days.

I also want to offer my thanks to those scholars, curators and cultural leaders who accepted my invitation to lead the conference thematic sessions as peer reviewers and Track Chairs, including: Beno Juaréz, Director, FabLab Peru; Assistant Professor Carla Paoliello, of the Faculty of Fine Arts of the University of Lisbon; independent curator Ligaya Salazar; Jonathan Boyd, Reader in Jewellery and Head of the MA Programme in Ceramics and Glass at the RCA; and Heather Martin, design educator and Course Leader at Arts University Plymouth in Fashion Design. I want to also thank Nancy Diniz, Course Leader in MA Biodesign at Central Saint Martins for reviewing the abstracts for Track 04 and for her expert feedback on the papers which informed the session on post-natural creative practices.

I also wish to express our gratitude to sponsors Micronomy and Plymouth Art Weekender for their support in providing the funding, content or promotion of the conference and its participants.

I want to offer my gratitude to our city centre museum neighbour, The Box, for providing the venue at St Luke’s Church and for hosting our opening reception. Thanks also to sound designer Neil Rose, Course Leader in Film and Screen Arts at Arts University Plymouth, and Bristol-based artist Harriet Bowman for their live sound performance using glass sculptures.

Lastly, I want to thank my many Arts University Plymouth colleagues for their contribution in developing and producing the conference which resulted in the essays gathered in this volume. I am especially grateful to: Cat Edwards and Adam Levi who worked closely with me for a year to realise the conference; BA Student in Graphic Design, Jessika McCarron, who designed all of the conference branding and visual materials; Lauren Taverner-Brown, who heads our Brand and Communications team; Katie Elloway for her coordinating assistance with hospitality; Ian Hutchinson and Dr Alexandra Murphy for operational support and Tima Metcalfe for her very practical wisdom when this iteration of the conference was in its early stages. And a final offer of thanks to Jonah Garner, Academic Librarian and Digital Education Advisor, who worked closely with me as copy editor for Volume 9 of the Making Futures Journal and layout designer of the downloadable PDF version.

I’d like to express my sincere gratitude to all authors and participants in Making Futures 2024 and for the meaningful provocations and creative insights which you brought to the conference and its ideas.

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Beyond Objects: Materiality at the Edge of Making

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Beyond Objects, Materiality at the Edge of Making, the title and focus of this volume, expresses a desire to place the presumed inevitability of object making under closer scrutiny, and to do this in the context of the widespread knowledge of the climate crisis we face due to our current habits of linear production and vast industrialisation. It aims to ask questions about how the imperative to improve our relationship with the environment might be consistent with the production of objects of art and design, even those we celebrate for their power, beauty, social value and material invention.

This collection of essays expands the notion of the artisanal object beyond its visible registers to examine the territories of knowledge, inquiry and practice that are largely illegible—the conditions for object production that are shifting not only how we make crafted objects, but examines why we continue to make objects, consciously knowing their impact on the environment. As educators the authors explore the potential for a notion of creativity and a critical studio practice that is always informed by the full life-cycle dynamics of making—a thinking beyond merely an object's form or display, to consider its larger ecosystem which encompasses material selection, distribution, knowledge exchange, and equitable access. The collected thoughts here treat the pre- and post-of the object as not only critical to their form, but in many cases the primary work, where the object functions as material evidence of the relationship between people, community and place.

Moving toward a reconciliation between object making and a more holistic, regenerative creative relationship with the natural world, this volume asks how greater material knowledge opens up new roles for makers with a shift from a culture of extraction to a culture of material empathy. Aligned with the question posed by the conference on this relationship between creative authorship and the material intelligence of nature, the discussion revolves around the following:

Could an approach to design and craft characterised by a full lifecycle consciousness change the way we think and shape the material world, in order that our subjectivity as makers can be more aligned with the agency of nature?

Can we imagine an interface with the natural world that is more transformative than merely becoming "greener" in our customs and technologies?

Is there a contemporary creative role that seeks co-authorship with both the systems of nature and our digital infrastructure that can be a more resilient, living and generative form of material objecthood?

The indication seems to be, judging by the conference presentations and the essays selected for this iteration of the journal, that many of us answer 'yes' to these questions. Artists, artisans and designers increasingly share the idea that craft culture is going through a wholesale shift, motivated by a new and innovative identity which is less a romance with preserving the past toward a willingness to establish the fundamental building blocks of a creativity that bears witness to the forces of nature at every scale. It is apparent that ceramicists, weavers, glassmakers, textile designers, are collaborating with material scientists, chemists, physicists, biologists to meet in the overlapping spaces where they are ready to redefine, or more poignantly, refuse, a simple reductive division between the cultivated and the wild, the representational and the merely material.

These new creative materialists are caught at this moment between two energising forces—the urgency of climate change and its devastation, and the acceleration of our understanding of the material properties of matter that act as creative agents on behalf of life. Beyond biomimicry, biomorphism and the visual analogy of the perceivable world which has defined much art and craft over many generations, advanced biotechnologies, new and novel materials and cross-disciplinary art/science collaborations enable us to transcend historic dualisms between our observation of and our representations of the world, inviting us to understand the processes of life as those open to our reinvention, extension and protection. New biosynthetic materials and advances in material engineering, including molecular engineering, biophotovoltaics, bioprinting, natural sensing systems, memory materials, and other living technologies that utilise the behaviours of life itself, extend into the realm of design where they establish a vocabulary of living systems.

The divide between the code of materials and the code of computation has narrowed, placing us at a great threshold in human and social development where these living technologies equip us with an intimate, behavioural knowledge of life as material that can be reconfigured—a proximity that invites ethical and moral responses that are inseparable from aesthetic responses. This new proximity is also a challenge to our cultural drive to make objects in the first place, and to imagine an active (verb: crafting) rather than static (noun: craft) aesthetic paradigm, one based upon living, phenomenal notions of beauty beyond a Kantian dialectic set on juxtaposition between form and matter. We are poised at the precipice of a more intimate material reality, where we must ask ourselves new questions about the extent of our contribution to a better future and where the domain of the beautiful might now be located to enable that future.

Creating Materials for the Symbiocene – A Proposed Nomenclature

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Keywords: Biomaterials, Biodesign, Symbiocene, Systems of Production and Consumption, Material Library

Introduction

"For the largest part of our species existence, humans have negotiated relationships with our sensuous surroundings, exchanging possibilities with every flapping form, with each textured surface and shivering entity that we happened to focus on ...Today we participate almost exclusively with other humans and our own human-made technologies ... (Yet) we still need that which is other than ourselves and our own creations. We need to know the textures, the rhythms, the tastes of the bodily world and to distinguish between such tastes and those of our own invention."

-David Abram, "The Spell of the Sensuous" (2017)

Ecological Crisis and the Global Movement of Materials

The expansionist globalization mentality of the 1950s through present day, a period known as the "Great Acceleration" (Steffen, Broadgate, *et al.*, 2015) with its false promises of hyper-ecoefficiency through optimized supply chains (Hayden, 2014), has only exacerbated the ecological crisis. It is well-established that human impacts are surpassing the boundaries of ecological functionality of earth systems, putting all species at risk (Steffen, Richardson, *et al.*, 2015).

One cannot ignore the role of design in both creating and solving this crisis. The modern designer is often called upon to serve the political, economic, and industrial goals of extractive systems of production and consumption (Boehnert, 2018) despite widespread recognition of this tension between ecological necessities and human desires (Leach, Raworth and Rockström, 2013). Simply, the pace at which we attempt to meet 'human-centered design' expectations has put unreasonable pressures on our evolutionary origins in the context of other species (Borthwick, Tomitsch and Gaughwin, 2022; Davidová and Zavoleas, 2022). Besides the negative pressures related to our biophysical dependence on living systems, the disconnection from our ecological origins in the majority of our lives is creating a sense of species loneliness, presenting as eco-anxiety (Albrecht, 2020), nature-deficit disorder (Louv, 2008), and rising rates of mental illness in many cultures globally. We can no longer ignore that humans not only need nature in a utilitarian sense, but our physical health, emotional regulation, and social fabric depend on it (Williams, 2017).

The designer has a vital role to play in the creation of the materials and artefacts that will mark the coming phases of economic development in Post-Anthropocene societies (Davidová and Zavoleas, 2022). The transition from human-centred to pluriversal design paradigms is well-underway (Escobar, 2018) with practitioners and scholars calling for life-centred design (Borthwick, Tomitsch and Gaughwin, 2022) more-than-human design (Poikolainen Rosén *et al.*, 2025)nature-centered design (De Pauw, 2015; Ruano, 2019), multispecies design (Gatto and McCardle, 2019; Keune, 2021; Biggs *et al.*, 2024; Lohmann, 2024), and Symbiogenesis-based design (Durán-Vargas, 2019). The sheer number and diversity of those calling for broader epistemological inclusivity directs our attention to a persistent shift away from the human-centered Anthropocene to an emergent and inevitable Symbiocene (Albrecht, 2016; Verniers, 2022).

Code (2006) describes this situation in ecological thinking as: "not simply thinking about ecology or about the environment: it generates revisioned modes of engagement with knowledge, subjectivity, politics, ethics, science, citizenship, and agency, which pervade and reconfigure theory and practice alike (p.24)". She later continues that ecological thinking is an "epistemological inquiry away from autonomy-obsession toward an analysis explicitly cognizant of the fact that every cognitive act takes place at a point of intersection of innumerable relations, events, circumstances, and histories that make the knower and the known what they are, at that time. Ecological thinking analyzes the implications, for organisms, of living in certain kinds of environments, and the possibilities, for those organisms, of developing strategies to create and sustain environments conducive to a mutual empowerment that is exploitative neither of the habitat nor of other inhabitants (p. 269-70)".

Concurrently, there is a rising conversation about the role that materials play in connecting the designer to the embodied relationships with human artefacts, with a focus on material-driven design guiding the process (Karana *et al.*, 2015; Camere and Karana, 2018; Bak-Andersen, 2021). Most of the materials that currently dominate our lives are disconnected from their places of origin – generally an ocean away from their ecological homes. Plastics, derived from prehistoric photosynthesis, are ubiquitous yet anonymous. Few people know where the source of these materials originated, how they are produced, or what their impacts are. Plastics have left us as global citizens—everywhere and nowhere at the same time—detached from the ecosystems that shaped human evolution. In recent years, pressure has increased for systems of production and consumption to change drastically as circular economy principles become widely integrated across sectors. Transitioning from petroleum-derived to biologically-derived materials is a key aspect of this shift. Ecological thinking as described by Code (2006) is not merely an intellectual exercise but is also an extension of material selves in the material world.

However, simply replacing the current materials with 'more sustainable', 'green', or 'eco' materials will not fundamentally change our relationship with materials, how they are valued, or the extractive systems that create them. For that existential leap of perception, we must examine how our relational values of nature led us into the current ecological crisis and how renewed socio-emotional and eco-cultural forms of intelligence can guide our relationships with materials, artefacts, and systems of production and consumption.

The Influence of Relational Values of Nature on the Design of Human Artefacts

The current ecological crisis begins with the story of the deterministic scientific methods as one of the primary drivers of modern life, creating a situation in which human exceptionalism dominates all ecological circumstances. All other living beings became the 'other', rejected as inanimate and lacking intellect, allowing them to be utilized as resources (Gameau, D., 2023; Capra and Luisi, 2014; Jickling, 2018) Using Kellert's Values of Nature (1995), framework developed in relation to the Biophilia Hypothesis, the dominance of utilitarian, ecologistic-scientific, and dominionistic values of nature have dominated modern relationships with nature. Since the industrial revolution and the social, economic, and cultural homogenization that have accompanied globalized capitalism, the naturalistic, symbolic, humanistic, and moralistic values of nature have declined rapidly, in just a 250 short years of human history.

Modern design education has also furthered our disconnection with place, as the modern designer can quite easily produce an artifact of material or visual value without ever having interacted with its physicality. The act of making material artefacts through industrial processes rather than craft detached the role of the designer from the maker and the materials (Bak-Andersen, 2021). While the movement of material artefacts of daily life have historically accompanied the movement of human transporters, the artefacts of our time are most often unaccompanied by ownership in a relational sense. Neither their maker, nor their intended user interact with them for much of their life span and at the end of their useful lives, they are discarded to places completely unrecognizable from which they came. Most human artefacts today are globally everywhere, yet socially and ecologically nowhere.

The lively and material origins of our objects are disconnected from their autopoietic and symbiogenic origins (Durán-Vargas, 2019), leaving them decontextualized from their evolutionary homes in forests, valleys, oceans, plains, and rivers. From the perspective of the designer and the end user, systems of extraction are hidden in plain sight and the living, breathing, photosynthesizing raw materials from which the object came to be are even less obvious.

Creating Materials in the Transition to the Symbiocene

Emerging frameworks driving post-anthropocentric material design such as those described as living artefacts (Karana, Barati and Giaccardi, 2020; Kim, 2022; Karana *et al.*, 2023), material ecology (Antonelli and Burckhardt, 2020), and biodesign (Grushkin, 2016; Myers *et al.*, 2018) provide models for how designers can give agency to living beings in the creation of novel materials. These frameworks, however, remain diverse and loosely defined. The ethical boundaries and ecological consequences of biodesign have come to accept a wide array of experimental approaches, at times in tenuous relationship with the very fields that it was intending to confront – the systems of science, innovation, production, and consumption that have driven our current ecological crisis. These frameworks promise an alternative but face similar risks of exploitative mechanisms of production and consumption.

What is clear in this tenuous relationship is that the field of biodesign, the creation of biomaterials, and the designer's relationship with the organisms they employ to create living materials are not exempt from the epistemological constraints of a Western education (nor do I wish to imply that I am exempt from these epistemological constraints myself). To move through these constraints, designers must give careful consideration to the systems of value in which we co-create with other organisms and ecosystems and frequently revert to utilitarian systems of viewing and valuing nature. For example, agar, a derivative of red algae used widely in biodesigned materials, is often praised for its sustainability characteristics, however, without knowledge of its ecological origins. Similarly, materials like gelatin or kombucha are used without transparency regarding their native ecosystems or production impacts. Without careful attention to these contexts, biomaterials may replicate the same extractive and disconnected systems as petroleum-based plastics. While biodesigners have achieved immense success in early experimental phases, significant challenges remain regarding the scaling, manufacturing, and supply chains needed for the widespread adoption of biomaterials.

In this newly defined relational era of the Symbiocene, humans re-enter the ecologically material world as apperceptive participants - participants who are aware of their own participation - in the co-creation of materials with their origins in the biosphere and lithosphere. The transition to relational values of nature requires ecological thinking (Code, 2006) and embeddedness in an ecological epistemology in which we accept that "knowledge is embodied in interdependent living systems" (Campbell, 2008). In contrast to "epistemologies of mastery" (Code, 2006 p129), the designers of the Symbiocene must be well-equipped with ways to discuss, source, and engage with materials that supplant them firmly in the current ecological situation of the materials' origins. If biodesigners are to accomplish the intended impact of restorative ecological actions, the origins of our materials must be specifically situated in the biophysical, ecological, and geological context of extraction and production. The geopolitical and economic origins must become of lesser priority.

The Scaling Challenge and the Need for Terminology

The origins of products and their materials are notoriously difficult to trace (Rinaldi *et al.*, 2022; Ospital *et al.*, 2023). In some small-scale examples, experimentation with biologically- and ecologically derived material feedstocks at a local and regional level are traceable from producer to end-of-life (e.g., craft- or custom- made products). Product traceability will soon become the norm with new requirements for Digital Product Passports (European Union, 2024), but what remains to be seen is whether increased traceability will lead to a reduction in negative ecological and social impacts from systems of production and consumption. Knowing the geopolitical origins of a product or material does not reveal impacts. Nor does this geopolitical transparency give regulators, manufacturers, or customers specific data on the ecosystem services lost through the products life cycle. A more advanced and nuanced approach to traceability might include a detailed description of the ecological origins of each component of a material or product.

There are many ways to describe and categorize materials - material type (metals, polymers, composites, ceramics, natural materials, etc.), physical properties (hardness, density, transparency, elasticity, porosity, etc.), sensory attributes (texture, color, temperature, etc.), country of origin, environmental conditions of intended use, and many other nomenclatures to relate materials to our various ways of knowing and disciplinary perspectives. Each of these categorizations provides a unique relational value on the materials situated within cultural and disciplinary perspectives. Some are more technical while others are more application based, and often the descriptions fail to communicate easily across disciplines (Johnson, 2013; Wilkes *et al.*, 2016). Materials libraries, gaining population globally in recent decades, have developed various classification systems to organize their inventory and direct their users towards the most relevant samples for their needs. By definition, a classification system is both descriptive and limiting, and as such, the terminology assigned to materials in any classification system will guide how we think, feel, and imagine about various materials. The classification of materials is an opportunity to guide users into new ways of viewing and valuing not just the materials as they are, but also their feedstocks, origins, end-of-life considerations, and many other variables. As with any novel discipline, the terminology describing biomaterial systems requires careful consideration. The current focus on physical and performance properties of biomaterials fails to account for their ecological origins and places of production. However, given the global ecological crisis, there is a pressing need to align biodesign practices with bioregional specificities to address these gaps and to reconnect humans with their local ecological contexts.

Through advanced experimentation with biotextiles and biomaterials, biodesigners are re-purposing biologically derived industrial waste and sourcing feedstock materials from local ecological contexts. In many cases, however, the feedstock materials that are used to create biomaterials and biodesigned artefacts are not traceable themselves. As the global movement of biological materials remains pervasive, it prompts critical questions:

- How do our current descriptive terms in biomaterials and biodesign influence our perceptions of sustainability and our relationships with place?
- What does it mean to have a bioregionally adapted material lifecycle?
- How can biomaterials enable deeper engagement with ecosystems rather than perpetuating globalized production and consumption paradigms?

The primary objective of this material design project is to connect designers and users of materials to their ecoregional origins and develop a sense of symbiotic relational engagement with the organisms or origin. In the broader global context of systems of production and consumption, this research explores a proposed nomenclature for biomaterials that classifies materials not merely by their physical attributes but by their relationship to ecosystems and places of origin.

Methodology

To explore these questions, three main areas of interest were examined through two main methods. The two main areas of interest included Biomaterials and Biodesign Classification Terms and Materials Designed for the Symbiocene. These areas were explored using internet-based research and collaborative experimentation in the creation of biomaterials.

Biomaterials and Biodesign Classification Terms

The first area of focus was a review of the biomaterials and biodesign literature and commercial realm regarding descriptive terms of materials used as categorization. Given the recent emergence of biodesign in the academic literature, previous studies in this area have mostly been in the scientific literature related to the material sciences and the existing classification systems are relevant for technical audiences within the sub-category of biomaterials. The field of biodesign, on the other hand, as a disciplinary area is still emergent and the literature defining the field is distributed across various publications and areas of research within design. For this reason, the review of terms was limited to those within publications more closely related to design.

Additionally, a brief review of the classification systems used in material libraries was done. It should be noted that many materials libraries and databases are subscription-only or belong to educational institutions where access is limited. Many private, commercial entities view their classification systems as proprietary. Data in this area was generally difficult to locate and review and was consequently, not used in the outcomes of the research.

Materials Designed for the Symbiocene

The third area is the creation of new, experimental biomaterials using the proposed nomenclature and the exhibition of these materials for public display. The materials were created by design students, design faculty, and later by members of the public in a workshop format. A 'tagging' system of the nomenclature was used to guide the organization of the exhibition and herbarium-style samples of material feedstocks were displayed with the material samples. In an effort to connect participants and exhibition viewers with the ecological (rather than geopolitical) origins of the material feedstocks, the World Wildlife Fund's Ecoregion (World Wildlife Fund, 2017) mapping system was used to describe the origin of the feedstocks (when origin information could be identified).

Results and Discussion

Results of Biomaterials and Biodesign Classification Terms

Given the historical origins of biomaterials within the material science literature, classification terms are largely related to the performance of the materials or the material type. These categorization systems are derived from largely reductionist epistemologies and questions of livingness and ecological origins are generally beyond the scope of inquiry. For these reasons, this area of research was largely excluded.

Within biodesign, there is an emerging, yet loosely defined, organization of types of biodesign descriptions amongst design professionals. Within the field of biodesign, there are a plethora of terms used to describe materials including: grown, living, biopolymer, bioplastic, bio-based, bacterial cellulose, mycelium, biofabricated, regenerative, and many others. This list is not intended to be exhaustive, but rather exemplary a quickly growing nomenclature describing materials within an emergent discipline.

To date, some classification systems in biodesign have been proposed. For instance, one proposal separates biodesign into living organisms and dead biomass (Esat and Ahmed-Kristensen, 2018). Similarly, the framework of 'healing materialities' guides designers to connect the biodesign and regenerative design approaches to surpass sustainability in a technocratic paradigm(Pollini and Rognoli, 2024). "Living artefacts" are those that are or were once grown by a living organism to develop the material (Karana *et al.*, 2023) and "grow-made" objects have similar production methods (Keune, 2017; Williams and Collet, 2021). "Material biographies" have also been proposed as a narrative solution to better transparency of the origins of biomaterials and their feedstocks (Rognoli *et al.*, 2022). These and many other design researchers have provided names and definitions to define nuances within the field of biodesign and reshape the way we feel about materials. These names direct our thinking towards new ways of interacting and engaging with all types of materials - living, once living, or never living. To describe an artefact of design as 'living' (Karana, Barati and Giaccardi, 2020)is to challenge to our senses and perceptions of life and the agency of designed objects.

None of these descriptions are exhaustive, nor do they purport to be. Rather they define the relationship between terms in an emerging new language of understanding and relating to other species through our material world. We have yet to thoroughly understand ourselves in this context, where the modern influences of science, design, ecology, and pluralistic humanity engage in modern living ecologies. It is reasonable that we shall all struggle to name these new experiences and try to connect to our existing frameworks of knowledge. None of them should be considered mutually exclusive and we should expect to see new clarifying terms emerge as the Symbiocene becomes fully realized.

Results of Materials Designed for the Symbiocene

Experimentation with the creation of biomaterials to connect designers and users to feedstock origins and their own symbiotic relationships with materials began in the fall of 2024 and is continuing with several student and faculty collaborators. Contributors to the collection of biomaterials designed for the Symbiocene are tasked with creating material samples using feedstocks of identified origins, positioning those feedstocks within an ecoregional context, telling the ecological origin story of the materials, and categorizing the material using the terms presented in the proposed nomenclature described in detail below. The material samples were developed into a material library format and displayed for public interaction. Contributors quickly identified that there is a lack of transparency in most material feedstocks that are readily available for purchase and were asked to describe the ecoregional origins of these materials as "Unknown".

Proposed Nomenclature for Material Design in the Symbiocene

This research proposes a nomenclature to reconnect designers, students, and consumers with their local bioregions through material tagging and identification systems. The original complete proposed list of thirteen terms included a nuanced collection derived from several disciplinary areas, such including ecological sciences, economics and business, social sciences, and design disciplines. This list is not exhaustive, but rather a more thorough representation of the terms currently used in the biodesign literature in an inconsistent way.

- **Ecological:** Sourced, processed, or used in ways that minimize environmental impact and support the health of ecosystems.
- **Biological:** Derived from living organisms, including plants, animals, and microorganisms. Sometimes, but not necessarily, offering renewable and biodegradable end-of-life solutions.
- **Living:** Alive or maintain living cells, often used in biodesign where the material continues to grow or change over time.
- **Regenerative**: Produced in a way that not only avoids depleting resources but also restores or enhances the surrounding ecosystem, often turning waste into valuable resources.
- **Biosequestered:** Feedstocks have absorbed and stored carbon, heavy metals, or other pollutants from the environment, contributing to environmental cleanup (e.g., "Salmon Gold" which is mined from mining waste sedimentation ponds using bacterial sequestration (Resolve, 2024)).
- **Imported:** Brought into a region from another area, often for specific purposes, without necessarily integrating into the local ecosystem.
- **Native:** Originate from and have evolved within a particular region or ecosystem over a long period, naturally adapting to the local environment.
- **Indigenous:** Naturally occurring in a specific region, often synonymous with native but can emphasize cultural and historical significance.
- **Endemic:** Uniquely found only in a particular geographic area, often highly specialized and not found elsewhere.
- **Naturalized:** Non-native but have adapted to a new environment and now grow or occur naturally in that region without human intervention. Do not demonstrate invasive characteristics.
- **Domesticated:** Selectively bred or genetically modified by humans to enhance certain traits, making them more useful or manageable for human purposes.
- **Introduced:** Brought to new regions by human activity, either intentionally or accidentally, and established themselves in the local environment.
- **Invasive:** Non-native materials that disrupt local ecosystems by outcompeting native species, often leading to ecological imbalances.

The application of these terms evokes various emotional and relational responses when used to describe a material, feedstock, or the species that grew the feedstock. Some terms, for instance, are more anthropocentric while others are more ecocentric. Terms such as *imported* and *domesticated* are more commonly used to serve socio-political interests. To the contrary, words such as *living, endemic, regenerative*, and *native* are frequently more associated with interests of ecosystems. Furthermore, some of these terms induce more utilitarian values of natural systems while others in induce more intrinsic values. For instance, terms such as *imported, introduced*, and *domesticated* suggest that living species are at human disposal for use, while other terms such as *native, endemic*, and *indigenous* provide a more intrinsic value framing of these other species who deserve value because they are.

To provide two examples of the application of the nomenclature, we will consider materials made from eucalyptus and those made from water hyacinth. Eucalyptus is native to Australia where it is well-adapted to the local soil types and is domesticated for regenerative planting strategies to restore local ecological balance. Eucalyptus in Portugal, on the other hand, is a domesticated species which has been introduced into a foreign ecological context where it behaves as an invasive species. In the Portuguese coastal ecoregion, it alters the native soil types out of ecological balance, changing the fire cycle of the local ecosystem. It also reduces the levels of native biodiversity through the homogenization of production. While eucalyptus provides the same basic feedstock of paper pulp from these two ecoregional contexts, cultivation of this species has significant impact on the stability of biotic systems in each respective place.

Water hyacinth as another example of a species that is well-adapted and symbiotic balance in one ecosystem but aggressively invasive in others. Native to Brazil, it is relatively stable in its native range and does not demonstrate any negative ecological consequences. However, in parts of Africa and Southeast Asia, it is aggressively invasive, clogging waterways, disturbing ecological balance, and disrupting economic activity. In these African and Southeast Asian contexts, it is harvested to remove the harmful effects, dried into a material that can be woven, and used to make baskets that are sold to international consumers at companies worldwide. To the contrary, the extraction of water hyacinth in a Brazilian context causes ecological harm because it removes the water purification and pollination benefits that water hyacinth provides within its native ecosystem. In the African and Southeast Asian context, this material has been commodified to avoid negative ecological impacts can be considered regenerative because it is actively healing and restoring the native systems.

These two examples demonstrate how the very same species can have vastly distinct ecological impacts, depending on the ecoregion of origin. And to date, there are few to no transparent systems in place to enable customers, designers, or policymakers to engage in a meaningful way with the gravity of these inherent issues. A more nuanced nomenclature is a first attempt to shed light on this issue within the field of biodesign.

Upon further reflection and practical application, the nuanced definitions of thirteen terms were difficult to apply when many of the material feedstocks were untraceable and others were not relevant to any of the materials created. Endemic, for instance, signifies extremely specific ecoregional origins and was not yet applicable within the context of highly globalized supply chains. Other terms such as native/indigenous and imported/introduced have meaning in specific disciplinary contexts but lose their nuanced necessity in the context of biomaterials and design.

Other practical issues emerged in using the more robust tagging system such as how to communicate such complexity in communication with the public and creating a visual language that retained its meaning for users and exhibition viewers without the need for additional oral explanation. For these reasons, the final nomenclature included the following terms:

- **Ecological:** Sourced, processed, or used in ways that minimize environmental impact and support the health of ecosystems.
- **Biological:** Derived from living organisms, including plants, animals, and microorganisms. Sometimes, but not necessarily, offering renewable and biodegradable end-of-life solutions.
- **Living:** Alive or maintain living cells, often used in biodesign where the material continues to grow or change over time.
- **Regenerative**: Produced in a way that not only avoids depleting resources but also restores or enhances the surrounding ecosystem, often turning waste into valuable resources.
- **Biosequestered:** Feedstocks have absorbed and stored carbon, heavy metals, or other pollutants from the environment, contributing to environmental cleanup (e.g., "Salmon Gold" which is mined from mining waste sedimentation ponds using bacterial sequestration (Resolve, 2024)).
- **Native:** Originate from and have evolved within a particular region or ecosystem over a long period, naturally adapting to the local environment, often with indigenous significance.
- **Naturalized:** Non-native but have adapted to a new environment and now grow or occur naturally in that region without human intervention. Do not demonstrate invasive characteristics.
- **Domesticated:** Selectively bred or genetically modified by humans to enhance certain traits, making them more useful or manageable for human purposes.
- **Introduced:** Brought to new regions by human activity, either intentionally or accidentally, and established themselves in the local environment.
- **Invasive:** Non-native materials that disrupt local ecosystems by outcompeting native species, often leading to ecological imbalances.

Notice that the term ‘local’, though widely used to describe materials, was intentionally excluded from this nomenclature as it does not provide any information regarding the ecological origins of the material. In practice, it does not differentiate between feedstock species that are locally domesticated and those that are native, nor does it imply any positive ecological impacts beyond a lowered transportation footprint. In general, its overuse in everyday communication makes it less relevant in the context of sustainability.

Conclusion

Materials in the Symbiocene and a Vision for the Future

Glenn Albrecht's (2016) *Symbiocene* envisions a future where humans exist in symbiotic relationships with ecosystems. To achieve this, we must rethink the language and classifications we use to describe materials. Plastic, for example, could be recognized as a *prehistoric biomaterial*, reflecting its origins and impacts. Biomaterials of today, however, must be understood within their current ecological, social, and cultural contexts. The proposed nomenclature aligns with this vision by creating language to facilitate transparency around material origins and impacts. It empowers designers, consumers, and policymakers to engage more deeply with their local and global ecoregions and make more informed material choices.

Existing material libraries categorize materials by type (e.g., mineral-derived, protein-derived, polymers, textiles) but rarely connect them to ecological or geographic origins. This research advocates for integrating eco-regional classifications, such as those proposed by the World Wildlife Fund's Ecoregions Map (World Wildlife Fund, 2017), to reconnect materials to their places of origin. By identifying the specific ecosystems from which materials are sourced, we can:

- Foster greater accountability in systems of production and consumption.
- Enable consumers to understand material impacts on local and global scales.
- Support biodesigners in creating regionally adapted, symbiotic production processes.
- Develop relational, embodied, material connections between humans and more-than-human species.

This level of transparency helps prevent the replication of extractive systems under the guise of sustainability.

The emerging dominance of biomaterials in our daily lives offers an opportunity to transcend the extractive systems of the Anthropocene and enter the Symbiocene. However, this requires a fundamental shift in how we classify, understand, and feel about materials. The proposed nomenclature serves as a step toward this shift by reconnecting materials to their ecological and cultural origins. To know a material only as "plastic" or "biomaterial" is to ignore its complex visceral relationships between ecosystems and humans. By introducing a system of tagging and identification rooted in ecological contexts, we can inspire new ways of knowing and engaging with materials—ways that honor their origins and foster symbiotic relationships between humans and the rest of the living, breathing, growing, nurturing, sensing, feeling, communicating species with whom we share our dynamic and quickly changing world.

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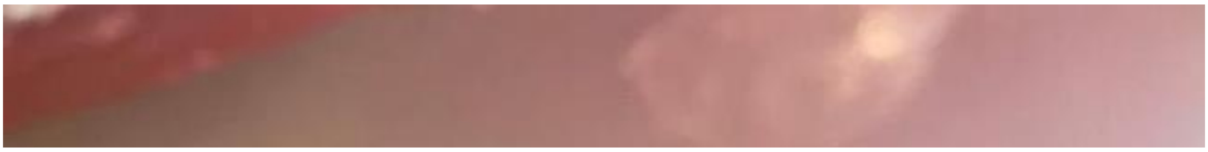

Towards Ecological Citizenship in social housing through Making Nature Principles and an Ecology-of-Things

Dr Nick Gant, James Tooze and **Alice Eldridge**

Keywords: Regenerative, Making, Nature, Biodiversity, Housing

Introduction

This research was undertaken through an inter-disciplinary and cross-sectorial collaboration for practical insight and understanding between arts and science researchers, local government and industry stakeholders and land managers. This paper documents part of a process of funded research that seeks to apply *Making Nature Principles* (Gant, 2020) to the creation of regenerative objects and products for social housing in Sussex, UK. The products are developed to provide sustainable alternatives in a local authority-housing sector facing policy demands for net-zero targets, Local Nature Recovery Strategy (LNRS) and Biodiversity Net Gain (BNG) whilst also needing to ensure cost effective and practical value to diverse range of citizens and stakeholders. We approach the research with the hypothesis that Sussex (a highly wooded county) could / should be able to contribute to sustainable, local timber resources for social housing with potential cascading benefits for society, economy and the environment.

The research also sits within wider, emergent and proliferating notions that craft has its roots in nature (Niedderer & Townsend 2022), seeing designers and makers as having agency as 'cultivators', co-working with natural systems (Collet 2020). Researchers suggest design and craft being in *partnership* with nature (Fletcher et al 2019) with an 'essential' need for collaboration between science and design, going beyond *bio-mimicry* as means to form *new hybrid typologies*. It is asserted that *regenerative* and *circular design* can benefit nature (Ellen McArthur Foundation 2016), *bio-design* (Myers 2012) and *'nature-first'* perspectives (Cox 2019) can contribute to both human productivity and nature recovery as part of meeting *sustainable development goals e.g.* UNSDG 12 - Ensure sustainable consumption and production patterns. UNSDG 15 - Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss. Making Nature Principles (MNP) attempt to support greater *material literacy* (Gant 2017) through engagement and approaches that seek to ensure making and nature associations are more directly defined by makers, in collaboration with other disciplines to enact the profound change to design practice and theory that is required (Fletcher et al 2019).

Ecological science calls for "a place-based, use-inspired science of understanding and improving the dynamic relationship between ecosystem services and human well-being with spatially explicit methods" (Gibbons 2018, Wu 2013). In social housing currently, circular economy innovation is limited to technical advances mostly weighted to waste management (Marchesi & Tweed 2021). Our work responds to calls for greater engagement with socially focused, multi-local innovation (Srivarathan 2023, Manzini 2009). It responds to calls for definitive methodological approaches and sharable metrics that can help to measure success in regenerative housing development (Hes & Bush 2018) and progress knowledge in the application of landscape monitoring approaches and technologies that support 'eco-space' accessibility and the usability of ecological science (Brunbjerg et al 2017). Therefore our research design aims to address both the need for practical regenerative approaches in real communities whilst seeking methodological insights for *making research* that utilises accessible, applied ecology relevant to the maker community.

A more speculative component explored in the *Wild House* project aims to use networked creative technologies to augment natural products with audio and visual information in the creation of an Ecology-of-Things. Using sensory networks to playfully connect between products and the originating habitats of the materials they are derived from. Connecting people and nature-based making via technology, may seem jarring, but has a solid evidence-base and chimes with our location in an urban UNESCO Biosphere – a designation that challenges experimentation in ways to live harmoniously with nature. As prescient environmentalist Rachel Carson wrote: Yet in the UK urban wildlife is so depleted that people lack opportunity, leading to nature deprivation in 1 in 5 households in the UK (Friends of the Earth). At the same time, technology is ubiquitous and presents itself as an enabling tool for reconnection. Nature apps such as iNaturalist, Merlin, PlantSpotter and eBIRD educate, inspire and reconnect by bolstering receptivity through supporting identification of species and gamification of sightings. Studies show that audio-visual 'nature surrogacies' confer some of the advantages of real-world messy nature, conferring reductions in psychological and physiological and self-report markers of stress and anxiety (Meuwese et al 2021; Aldoh et al 2024), improvements in self-reported stress, anxiety, happiness (Palanica 2019) and sociality (van Houwelingen-Snippe et al 2020). To our knowledge, the potential bolstering ecological literacy and nature connection via augmented products is novel terrain.

Key research questions relative to the research include:

- Can woodlands and timber products help deliver more sustainable supply chains and products for social housing in Sussex?
- How might these products be designed to mediate greater material literacy in users?
- How might these products be augmented with creative technologies to enhance greater ecological literacy, engagement or connection?
- What research and development processes can support hybrid arts / science collaborations for more robust research of the maker / ecology relationship?

Methodology: Methods, stages, and techniques

Micro - approaches engage with the idiosyncrasies of local landscape, social, cultural and material contexts and are intended to be repeatable by makers (with limited ecological knowledge). And fundamentally this must also be practically purposed to deliver outcomes for local authority partners and social housing users in the locality

Macro – methods in support of multi-localism consider a regional network of necessary connectivity and collaboration across the geography - stakeholder engagement and literature reviews acknowledge that local concerns and insights will often have regional and wider relevance within a healthy mosaic of diverse places and habitats for people and nature

Meta – research methods embrace and observe the role of *propositional* research (Walker 2013) and creation of *in-forming things* (Gant 2024) and the agency of making as a distinct methodological approach -this being where theory and practice are entwined, where making embodies the theoretical hypothesis within the practical apparatus of research. Resulting objects serve as both manifestations of enquiry and proposed 'solution' within a format relevant to the context and culture where the research is intended.

Stage 1: Mapping and surveying

1.1 Timber mills were mapped and applied to a wiki-GIS digital map (Knowne & Gant, 2023). It maps mills as potential hubs for multi-local, *knots-in-the-network* of distributed resource and possible manufacture activity – The emerging map demonstrates relatively evenly geographic distribution of mills regionally.

1.2 The project also approach demanded engagement with the systemic issues associated with the complexity of woodland resourcing - giga-mapping woodland resources and the associated social and cultural aspects impacting their accessibility and their natural and geographic relevance and provenance. An initial giga-map was devised following informal interactions between stakeholders that merged hypothetical expectations and evidence expressed through academic and policy literature and established resource management methods for surveying woodlands.

1.3 'Sight Surveys' and ecosystem drawings and collages (Gant and Luffiansyah 2022) enabled primary research engagements with our subject woodlands enabling makers (as well as ecologists and land managers) to really notice the environment and draw connections between different aspects of the resource landscape, formal woodland management plans including the removal of resources and any associated potentials for habitat improvement.

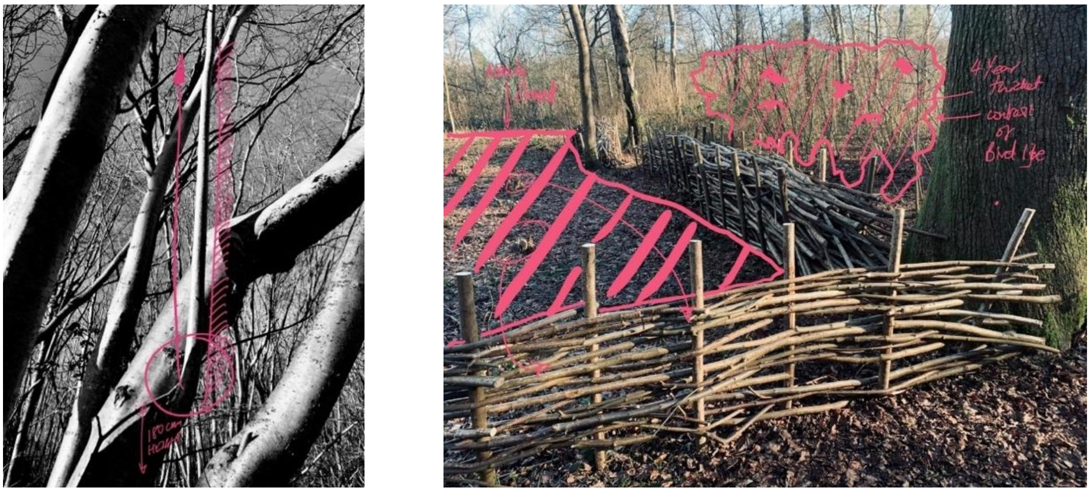

Fig 1. Nick Gant (no date) 'Sight-survey' identifying the lack of number and poor health of younger, straight / typically usable stems in the unmanaged woodland and variation in habitat / composition and variance of bird species of different stages of recently managed / coppiced areas.

1.4 Woodland acoustic monitoring

Fig 2. Nick Gant (no date) Monitoring variations in soundscapes between sites under differing woodland management strategies. Woodland management map (left) and autonomous recording unit (right).

The Woods to Outcomes project provided space to investigate affordable methods to investigate biodiversity impacts within *Making Nature*. Whilst Biodiversity Net gain considers habitat alone, we know that birds and butterflies, along with other species are omitted. Acoustic monitoring is gaining popularity in the space as a citizen-science friendly approach to assessing changes in bird communities (for example using BirdNET) as well as whole soundscapes (see Sueur and Farina et al).

Within the constraints of practicality and funding these approaches seek to combine a range of disciplinary expertise and experience – This is undertaken as a means to reconcile the anxieties that 'non experts' (e.g. makers) have expressed in terms of the intimidating weight of ecological scientific knowledge when considering the adaptation and augmentation of their knowledge when trying to unlock progress towards genuinely regenerative actions (Gant and Luffiansyah, 2022). This whilst also acknowledging that ecological science itself needs to be applied and applicable to situations and communities where it is useful and can contribute to sustainable development.

Stage 2: Making prototypes

2.2. Kitchen Doors

To further explore how timber products from local woodlands can help deliver more sustainable supply chains and products for social housing in Sussex, prototype kitchen cabinet doors were designed and made. These have been installed in the Waste House, as part of the *Wild House* project to test their desirability, dimensional stability, and durability. Kitchen doors were selected as the local authority has a schedule of works that includes the need to install circa 300 kitchens a year (approx. 3000 doors) for the next 25 years in council managed properties. In addition, many hundreds of metres of skirting board, architrave, door frames and other furniture, fittings and equipment products. An assumption in the project team was that with a local authority as the principal customer in the supply chain, it offers the opportunity to take a longer-term and strategic approach, better connecting procurement with other responsibilities and targets the authority has. By sourcing from local woodland owners, this could encourage investment and longer-term planning that supports local woodland, mills, joiners, and others in the supply chain. The local authority has a stake in the viability of rural economies, as well as the resilience and biodiversity of the natural landscape. This longer-term approach fits well with woodland managers, who too need to take a medium to long-term view, both as custodians of the land they oversee but also of the economic viability of the stock they manage.

An example of how such longer-term thinking could impact the supply chain is the creation of a standard dimension (width and thickness) plank of sawn timber that could allow smaller woodland owners to better estimate the value of the timber stock they hold. The notion of this 'Sussex plank' came from conversations with mills, timber suppliers and others in the timber supply chain that posited that if a range of products were designed to utilise this plank size, especially for those with longer-term procurement plans the predictable demand in the future would encourage planting and management of suitable tree species and confidence of a financial yield of greater value than that of biomass. The design of the doors were informed using a standard plank, considering factors such as differing shrinkage and distortion rates as different timber species dried out. In addition to its sawn dimension, the Sussex Plank, would be characterised by the species of tree grown in the region, that are suitable for interior joinery and have a predicted yield that would enable felling for production. This includes softwoods such as Scots Pine, Douglas fir, Hemlock and Larch and hardwoods such as English Oak, Common Beech, Ash, Sycamore, Sweet Chestnut, Hornbeam and Silver Birch. While feasible to use softwood planks to produce skirting boards, hardwood is more suitable for both worktops and doors. Hardwoods due to their small, tightly packed cell structure exhibit greater dimensional stability and resistance to moisture-related changes than softwoods, especially in environments like kitchens with fluctuating humidity levels. Where skirting boards may be fixed in place and painted over, both serving to protect them from absorbing moisture from the surrounding air, and to limit their movement, they are also singular planks, meaning that slight changes in dimension (±2mm) will likely go unnoticed. This is not the same for complex assemblies such doors, where dimensional changes to components can be immediately visible and impact on the functionality, by twisting or swelling.

For the prototypes Sweet Chestnut, Ash and Oak were selected as they are key and fairly abundant hardwoods in the South East of the UK, with an established supply chain, and will continue to be important unless adversely affected by climate change, new pests or disease. In fact, predicted scenarios for climate warming over the 21st century indicate that conditions favouring chestnut will be enhanced, and in particular for the South East. Over the next 50 years, Sweet Chestnut has the greatest potential for growth and productivity of any broadleaf tree in the UK (Forestry Commission, 2014). The doors, in addition to ascertaining their financial viability as products, were created to explore whether a responsive and multi-species approach could be taken to material sourcing that would be reflective of more (bio)diverse and resilient woodlands.

Fig 3. Nick Gant (no date) Multi-species kitchen cupboard (James Tooze and Nick Gant) door embracing healthier more diverse woodlands and utilising the 'Sussex Plank' standardisation of timber resources to increase affordability and efficiency of resources.

2.3. Sussex S.E.E chair

Our featured case study uses timber locally defined as 'weed-wood' relative to the restoration of formerly unmanaged woodlands, some of which have relative monocultures of overgrown species that colonised following the great 1986 storm and is seen as potentially representative of many under managed woodlands in Sussex (Gant et al, 2024).

The Sussex S.E.E chair represents an open design challenge to (re)engage with what was The William Morris company's most successful chair, which shares a geographic interest as well as other intrinsic principles and purposes. The chairs developed (so far) in this project approach the physicality and processing of the object through nuanced perspectives relative to proposed benefits to Society, Economy and Environment. Borrowing from Elkington's notion of the *triple-bottom-line* (Elkington,1999) iterations of the Sussex S.E.E chair dial in aspects of social (S), environmental (E) and economic (E) value manifest through the making process. This embodying process affords opportunities to develop a user / object interaction mediated through a defined material language within an everyday product.

Fig 4. Nick Gant (no date) Sussex S.E.E chair v1.1 and v1.2 (Nick Gant and Jason Mosseri).

The team included design and craft academics and students and a respected traditional chair maker. We explored chair types where the underlying design / making direction is conceived through the structuring of the making principles and in response to the possibility of how makers of differing skill levels may access engage. Different interactions combine primary inputs driven by the species and size of timber (considered of little or no value due to the lack of management). For example, Sycamore in particular, as a pioneer species (Szwagrzyk et al, 2018), is invasive and useful and provides a very flat-white finish. Hazel was left in with bark attached and by only using a draw knife, very basic versions of the chair are easy to access in terms of skill and use of abundant material felled at a size with little application - even for firewood. Unlike Morris' originals, our chairs are simpler in structure and refer to the kinds of construction and making principles similar to Curtis Buchanan's 'Democratic Chair' (Buchanan).

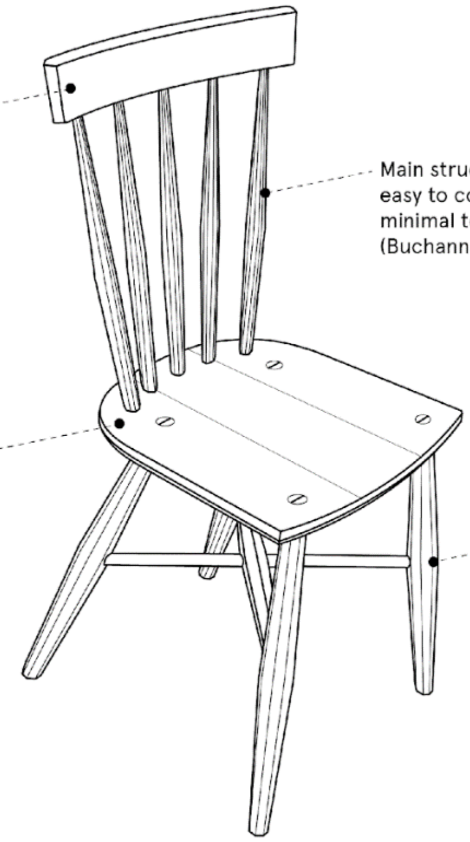

Fig 5. Nick Gant (no date) Critical framework of version 1.1 of Sussex S.E.E. chair (Nick Gant) composing visual / material and making language and using the easiest, most accessible making techniques for future production by charities that utilise making for health and well being.

2.3 Ecology of Things – this borrows from the established notion of Internet of Things (Ashton, 1999) where internet enabled or 'smart' objects and products are able to sense, interact and share information as part of a connected network. In our case objects that use digital and / or material interactions and communication media to highlight their part in a landscape resourcing and natural habitat eco-system. Example being our multi-species timber kitchen units that play sounds derived from sonic sensors that are in inaccessible natural environments this includes bird song from private woodlands where the timber resourcing is improving habitats for these species or augmented reality used to beam users into the resource woodland using the cupboard as a portal.

Fig 6. Nick Gant (no date) Multi-species kitchen cupboard uses augmented reality to beam users into the resourcing woodland via a panoramic video and binocular interface (Nick Gant and James McAdam).

Results: Key findings or expected results

Prototypes

The team developed a range of prototypes that included focused investment in the development of a range of hardwood kitchen doors. These demonstrated that a multi-species approach was technically possible with different configurations providing better results against shrinkage and movement. The mixed species approach could make for desirable products (following user testing) that are better reflective of the healthier, more diverse and resilient woodlands that we need within a sustainable, mosaic landscape. Moreover, the notion of a 'Sussex plank' was devised to reverse the *designer as specifier* orthodoxy in favour of mills developing standardised planks from a much broader range of species, with designs being versatile in accommodating this. The run, mix and range of materials are, in reality, unlikely to lead to much mixture within one door / kitchen but could become a desirable method for optimisation. The value of such products may also benefit from being presented as products alongside accompanying resourcing narratives associated with their provenance and role within local social, economic and environmental value chains. To this end we have generated integrated technologies that form an Ecology of Things (EoT). These provide material and immaterial, direct and indirect interactions with the landscape that may surface the connectivity between humans and other species mediated by the material things that surround us.

The Sussex S.E.E chair emerged out of a programmatic response to a set of both criteria defined by the context and more open aesthetic opportunities to explore what wilder-wood objects might look like and convey through the material language of the object. 'Wonky, weed, woods' in this case small diameter sycamore, hazel and ash provide specific starting points and outcomes with idiosyncrasies that we embrace and exploit, seeking to enhance their contribution and values through the object narrative. Versions of a Sussex S.E.E Chair have demonstrated the direct use of low-grade timber prevalent after storms and unmanaged woods. It is often left standing and / or extracted and left onsite or burned limiting the potential to improve and diversify habitats and the woodland health.

The state of our wood(s)

The project was developed on assumptions, policy documents and industry commentary that suggest that, in effect, there are woods out there nearby (in Sussex) and we should be using them in sustainable local housing for a range of reasons. Collective first hand experience, literature and stakeholder insight and feedback demonstrates that the situation is complex and in reality we need better woodland management to enable a coherent supply chain in the future. Woodland is being presented as a key mediator of climate related emissions – literature suggests that older stands, coppicing and hardwood as well as softwood species need to form part of an effective mix and the greater use of different timber products will be necessary to realise these ambitions (Burton et al, 2018). We were often frustrated by a lack of exchange of data and knowledge and of the collaboration that is necessary between actors to generate an efficient and productive supply chain at scale that will meet the multiple metrics for social housing. Mapping mills provided an overview of how their relatively even distribution throughout the region that might support multi-local hubs for storage and possibly manufacture of standardised products from simple skirting boards and in some case more complex products – however greater collaboration would be required to ensure optimisation of different timbers within the supply chain.

Value(s) accounting in product development.

Within the evident and obvious economic constraints associated with the delivery of products for social housing sector we developed a very detailed costing model - not detailed for this paper (Gant, et al, 2024). However with each product we encountered the need and opportunity to consider for value accounting as what may in principle be 'cheaper' financially may have other forms of 'cost' within the supply chain. Locally sourced timber could enact more *virtuous-circular-economies* (Gant, 2020) within the region that seek to acknowledge the contribution woodland, resource and product management can facilitate against a range of potential benefits. Engaging value(s) accounting there are evident social 'values' that could be delivered through the use of a local sustainable, timber supply chain and products. Our prototypes have indicated need for collaboration to overcome the many inhibiting factors – but this can lead to higher levels of value in developing multi-local-systems for social, cultural, environmental, and economic sustainability and improvement enacted by developing the current models. A ledger concept that forms part of digital augmentation and communication channel delivered through the products helps to ensure users are included in the narratives associated with their everyday products. These integrate messaging within the products themselves about wider positive values enabled through local resourcing (see augmented experiences). *Tree-to-table* value mapping could be further enhanced through 'well-making' initiatives with charitable and social value partners engaged in making as a means to improve mental health and well-being in vulnerable groups (for example). Robust scientific underpinnings for claims associated with carbon reduction, biodiversity benefit as well as social values within this (local) context all need greater scrutiny and research.

Collaboration:

Issues and opportunities associated with sustainable development often require significant collaboration to change the 'status quo' - The development of even simple timber supply chains that can realistically utilise 'what's actually out there' require greater collaboration. Our experiences concur with other researcher's published assessment that "levels of collaboration are low and use predominantly horizontal mechanisms, focusing on information sharing rather than joint operation. This is despite a positive market opportunity and a growth aspiration" (Greenslade, et al, 2020).

Storage

The project demonstrated a need for locally centralised storage and drying facilities that could stockpile and *hedge* timber investment for use in the social housing market. These would support optimisation of mixed species stocks of 'planks' that can translate into the range of products, helping to diversify the market opportunity away from more polarised low value biomass / firewood and higher graded lumber inaccessible for social housing procurement.

Data

A sustainable production process feeding reliable resource stocks will require more accessible data related to (for example)

- the currency and efficacy of woodland management planning in the region and possible yields associated with felling licences when approved.
- open and collaborative model that uses mapping and management software could support a localised market and management system useful for the supply chain.
- development of practical, applied ecological data to underpin value systems associated with nature-recovery / benefit through timber supply chain management.
- social housing user assessment evaluation

Biodiversity drivers

Nature preservation and improvement appears to be a multi stakeholder concern that may present an opportunity to unite interests of both public and private landowners, social housing suppliers and service users. Landowners suggest nature and biodiversity is presented as a key driver and aspiration for large public sector and privately owned estates as well as with smaller private owners – Our social housing supply chain can help 'wipe the face' (economically) of nature-prioritising operations, particularly if it can (literally) *make the case* for products and resourcing models that have demonstrable and tangible, positive impacts on nature locally. Moreover if our initiatives that support land owner understanding and engagement with timber development processes that champion 'making nature' and the growth of 'productive habitats' (Gant, 2022) this could, in turn, motivate better management practices through a mutual value chain. This may counteract and unlock limiting factors (Greenslade et al, 2020) and perceptions such as *moat-making* around private properties towards keenness for felling as part of biodiversity gain. New opportunities could concur with the principle (if not the specific means, metrics and measures) for policy initiatives such as Biodiversity Net-Gain (BNG) and Local Nature Recovery Strategies (LNRS) generated through utilisation of nature prioritising or benefiting supply chain processes and design. Presumptions regarding what social housing tenants would aspire to and engage with need further research but we are confident the current prototypes represent a quality outcome, with a valuable narratives attached. We have modelled initial devices for connecting users to the landscape through digital and physical material interactions that manifest through an Ecology-of-Things that can enhance experience, understanding and appreciation of the stuff that surrounds them (Gant et al, 2024). Therefore through further research and testing can we lock-down this potential through the development of fully realised and marketable products that embody this complexity (?)

Discussion: Contribution and impact

Practical and speculative

The research has developed insights into the practical delivery of locally sourced timber products intended for social housing in Sussex and more emergent, speculative frameworks for research that are less tangible but are guiding the next phases of research. These are seen as mutually beneficial and interrelated in terms of developing understandings and meaningful connections throughout the supply chain - from the motivations to management more bio diverse landscapes through to the end-product / user interactions. Moreover we value the transformative act of making, and the made object, as a vehicle for both research and a key point of human and more-than-human connectivity and mediation. The criticality of the object transcends its practical purpose to embody a set of systemic issues and opportunities whilst attempting to mediate this complexity through the material language used in its 'making'.

Making research often provides methodological insight as a contribution and outcome in its own right. The project presents the making of objects as 'in-forming things' (Gant, 2024) - these typically integrate approach and insight, being both apparatus and artefact of research; they embody findings that delineate the direct nature-net-gain potentials of social housing products and ways in which this process might be enhanced through the material (and making) experience. We engage with the making of 'products' where the objectification of *research-through-making* ensures the practical apparatus of purposeful, practice-based-research also affords opportunities to deliver new insights into the wider social, cultural and environmental dynamic. Mixed method ecological and visual 'sight surveys' and acoustic monitoring of woodlands attempt to ascertain potential enhancements to nature as an integrated and user-centred approach to the development of an *ecology-of-things*. This approach seeks to be deliberate in an attempt to map and define the interrelationship between the habitats of people as nature reconciled through everyday objects as a form of *Ecological Citizenship*. Moreover it places 'the maker' as the facilitator, custodian and curator within these connections. The Making Nature principles methodology applied attempt to make (literally and materially) direct correlations between specific and identifiable habitat improvement and biodiversity as a direct result of the making process. Moreover these interconnections are enhanced to reconcile the product users (in this case social housing tenants) and the landscape, flora and fauna to enact a tangible experience of co-existence mediated by materials. The research agenda now is to map the longer-term impact of the intervention – ecological surveys / on going sight surveys to increase maker engagement with the state of change enacted through the resourcing model. Other limitations of the research necessitate inviting stakeholders to review prototypes through a 'show home' social house set up at The Waste House University of Brighton - this to test assumptions about social housing users aspirations and preferences for more regenerative and localised materials, objects and spaces. We seek to further develop methods for woodland owners to use and benefit from accessible technology for wildlife monitoring and evaluation in support of motivated wood management for nature (and timber). This requires further hybrid scientific protocols, demonstrators and design solutions to support authentic data development alongside rewarding and user-friendly interfaces for engagement with research. Moreover we ultimately aim to curate and test opportunities to more explicitly promote the parallels between the *making of things* with *bio-diversity net gain* and to elevate the value of Making Nature Principles through EoT enabled Sussex S.E.E. Chairs that mediate this biodiversity connectivity. We hope to assess manufacturing options that develop opportunities for local charities and new economic and 'making-well' (Hackney et al, 2023) initiatives that can unlock new 'branding', social value and identity aspects through partner organisations. Further explore interest in local social service and charitable and industrial sectors of regional design types and collaborations in the manufacture of branded regional product types that embody a range of social, environmental, cultural and economic opportunities.

The research findings demonstrate the probability and practical implications of nature-based approaches to the making of social housing products and experiences. The resulting objects materialise hybrid ecological and generative making methods via a combination of material and digitally augmented objects, experiences and interfaces that reveal and embody the inter-connectivity of human, plant and animal ecology. These approaches and outcomes provide a basis for discussing notions of co-authorship in the creative, generative development of things: They are dictated by the 'nature-of-making' demonstrating and testing the application of Making Nature Methods and revealing insights into the ways in which wider challenges of sustainable development meet the practical reality of social and industrial sectors and the habitats of humans and other forms of nature.

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Imaginary Order

A collaboration exploring waste, value and abjection in relation to materiality and aesthetics

Gayle Matthias and **Rachel Darbourne**

Keywords: Waste, value, abjection, corporeality collaboration

Introduction

This paper discusses the collaborative practice-led research project initiated by Gayle Matthias and Rachel Darbourne in 2023 and the resulting joint creative identity that emerged. Both are unconventional craft practitioners, kiln formed glass and jewellery practice are respective specialisms. The reappropriation and assemblage of waste objects and materials was a common shared methodology and situated their creative practice on the boundaries between craft and fine art and for the purposes of the paper they refer to themselves as 'the artists'.

They draw on a rich heritage of recycling and make do and mend, which has historical and cultural associations with thrift craft practice and the use of upcycled and reappropriated materials in the form of readymades and poor aesthetics which have close associations with contemporary conceptual art practices including; Dada, Arte Povera, and Process Art.

Central discussions included in this paper are:

i) The project intentions and collaborative creative methodologies, and the dissecting of dual artistic authorship documented by Charles Green. He identified three forms of artistic collaborations, those who had distinct visual identities such as Warhol and Basquiat, merged collaborators like the Chapman Brothers and the historical role of fabricators who facilitated artists' visions.

ii) The identification of four significant aspects/qualities of waste materials and objects that they wished to focus on in their collaboration, waste in relation to *Materiality,* the *Places* where this waste was acquired, the artist's *Relationships with Waste* materials and objects and the *Metaphorical* associations imbued in such materials that were exploited through the resulting hybrid assemblages.

iii) Theoretical frameworks with a focus on waste/discard theory that relate to material hierarchies, value and time, mortality and wider societal responses to waste. Drawing on the writing of Mary Douglas, William Viney and John Scanlan.

iv) The analysis of the collaborative outcomes and the impact of the collaborative work on individual and continued joint practice.

Besides the commonality of the reappropriation of waste materials and objects, Matthias and Darbourne have a keen interest in uncanny corporeal anatomical symbolism that encapsulates abjection; dysfunction; internal spaces and margins, and objects of longing and want that may reside in these spaces, as discussed by Sigmund Freud, Jacque Lacan and Julia Kristeva. Both balance this conceptual weight by incorporating irony, humour and innuendo.

Matthias's practice-led research is grounded in autoethnographic memories and lived experiences of growing up in The Potteries (Stoke-on-Trent); home of the heavy industries of ceramic, steel and coal and working class values. In particular the environmental and cultural contrast between her father's car body repair garage, an ultra masculine domain, and her mother's pristine life of domesticity. The garage housed grime, pungent fumes, and intriguing car innards and these objects are staples of Matthias's creative practice.

Matthias's most recent collection, Clean-up Workers (Deluxe Series) 2020 to date (Fig. 1.), unite worn domestic cleaning equipment with car body parts; waste by products and reappropriated work; alongside cast, blown and sheet glass to create dysfunctional anatomical vacuum cleaners. The artist's hybrid work draws on Lacan's psychological theories of the rim and the 'objet petit a', which represents all objects that temporarily satisfy emotional longing and are illustrated through the plugging of objects into marginal spaces, apertures/portals.

Darbourne's jewellery practice explores how creative input can impact and subvert two value systems: the emotional hierarchy that exists within object ownership and the values that are ascribed to materials. The series, Lovingly Murdered (Fig. 1), refers to the object relations theories of paediatrician and psychoanalyst, D, W. Winnicott, in particular the theories discussing the first 'not me' possession (Winnicott, 2005, p.2) and their impact on psychological development. The transitional object is chosen by the infant but 'Its fate is to be gradually allowed to be decathected, so that in the course of years it becomes not so much forgotten as relegated to limbo. It is not forgotten and it is not mourned.' (ibid p.7). It is this place of limbo where Darbourne's interest is focused, the residual adult memory and perhaps sentimentality, and how this impacts on the fate of the non-chosen transitional objects. These soft toys are purchased then deconstructed and used to explore ideas around transgression, taboo and humour. The work is sited on the body, this intimacy with the worn item adding to the concepts and narratives that the artist is researching.

Fig 1a. Matthias, G. (2021) *Clean Up Workers III (Deluxe Series)*.

Fig 1b. Darbourne, R. (2020) *Lovingly Murdered: Rhino*

This paper, through the nature of the collaboration and approach to creative practice, can be seen to enrich and broaden the critical debate within the fields of contemporary glass and jewellery. It builds on research contributions by: Helen Pailing's' Recrafting Waste...', 2019; Professor Jivan Astfalck et al, 'Beyond Junk:

The Complex Art of Value Hacking', 2017; Julia Manheim's subject specific book 'Sustainable Jewellery', 2009; and Veronica Sekules: The Art and Heritage of Waste, 2023 with an accompanying exhibition at Groundworks, amongst others.

Waste Theory

'Removal is a crucial aspect of the organization of the object world inasmuch as garbage is equated with externality both in material and psychological terms. It disappears outside into a different 'space' - a space that is beyond self perception and out of sight' (Scanlan, 2005, p.135).

Waste management, according to Scanlan, epitomises the advancements in western societies and reveals an aspect of human denial. Waste disposal jobs are designated to low status individuals, the reality of 'the death of an object', which could be understood as representative of human death, is therefore rarely confronted by the majority and dissolves individual responsibility. Within her influential book, 'Powers of Horror', Julia Kristeva also references corporeal waste expulsion and ultimately death. 'The corpse seen without God and outside of science, is the utmost of abjection. It is death infecting life'. (1982, p.4).

Writer and researcher William Viney also considered waste from a societal perspective and states that: 'Objects called 'waste' have a peculiarly telescopic effect on our imaginations. They are things that seem to disclose ways of living, permit certain ways of seeing and give access to wider actions, collectives and environments'. (2015, p.1).

In his efforts to categorise objects in their life-span time-line and in relation to waste, Viney describes objects as possessing a 'use time' and a 'waste time'. These two terms became particularly important when the artists considered the inexhaustible potential of the waste and its rejuvenation through reappropriation.

Within this paper the artists have used the term 'waste', to encapsulate: waste objects, waste materials and the waste by-products of their practice.

Collaborative Methodology

This collaborative research project provided a lens through which Matthias and Darbourne could explore their existing practices and collaborative opportunities.

At the commencement of the project, they laid out their waste to create a physical audit (Fig. 2). Consequently, they decided to define their understanding of waste in order to exploit its potential in the collaboration, by categorising waste under the headings of: *Materiality; Place; Relationships*; and *Metaphors*.

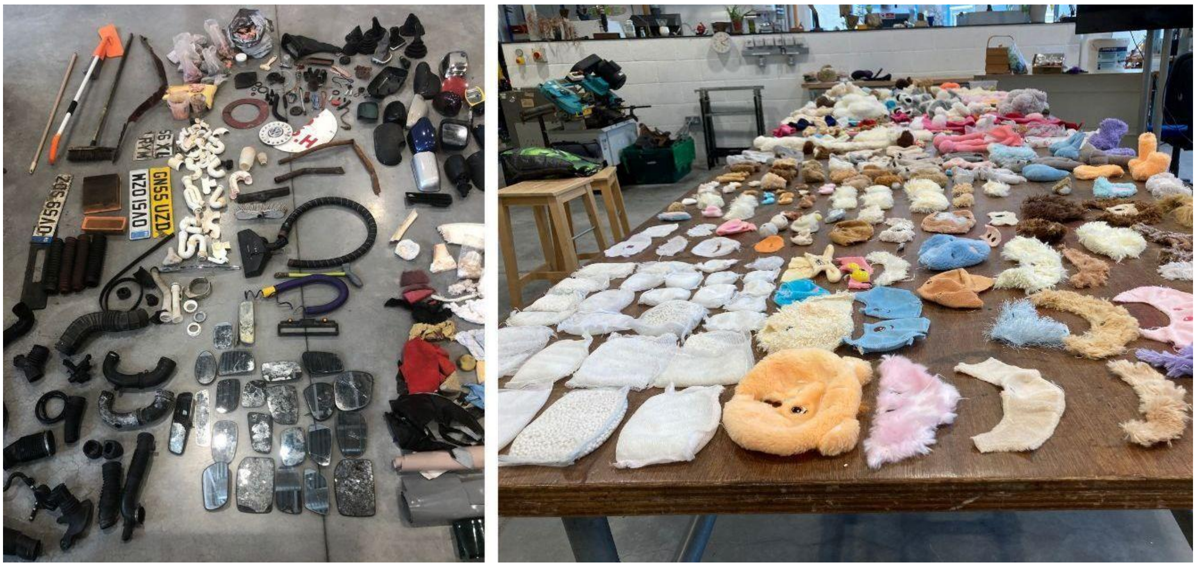

Fig. 2 Matthias, G. & Darbourne, R. (2024) *Waste Audits*

Materiality

The artists identified the differentiation and definition of waste materials and objects and the relationships to their established material libraries. Anthropologist, Mary Douglas categorises the different stages of degeneration of waste materials; the stage of objects/materials becoming disorderly. She states that, 'This is the stage at which they are dangerous: their half-identity still clings to them and the clarity of the scene in which they obtrude is impaired by their presence' (2002, p.197). Scanlan connects Douglas's theory with Freud's definition of the uncanny when he states, 'it is also our ignorance of ruin, decay, and so on, that renders garbage uncanny, unfamiliar or unhomely" (2005 p.167). Both artists regularly utilise the 'partial identity of things' as a disquieting aesthetic, resulting in work that is both familiar yet unfamiliar.

Mattias's aesthetics and material choices are epitomised by mass produced injection moulded plastic items found under the car bonnet; combined with plaster, wax and metal components. Glass in all its forms provides a contrast, mimesis and transparency. The approach to all objects was non hierarchical. These found objects have layers of grime that can be repulsive and non tactile, surfaces are hard, colours are muted.

Darbourne's aesthetics and material choices revolve around soft toys made from synthetic fabrics that are mass produced, cheap, garish in colour and usually badly made. Once purchased the toys are washed, removing the stains of previous lives, resulting in materials that smell of fabric conditioner.

Place

The artists identified and defined the significance of the non-places where waste could be found such as the verge, alleyway and breakers yards (Matthias) and sites of guilt free disposal such as the charity shop (Darbourne) where objects that may still be of value, get a last chance.

Augé describes non-places as transitory sites of supermodernity that are the real measure of our time.

'Place and non-place are rather like opposed polarities: the first is never completely erased and the second never totally completed; they are like palimpsests on which the scrambled game of identity and relations is ceaselessly rewritten'. (Augé,1982, pg.64)

The alleyway is an allocated place for rubbish bins, but as a non-place it is an abused public space of accidental spillages and wilful discarding, a site of 'half identity'. Douglas describes dirt as 'matter out of place', however, the waste in alleyways is in keeping with societal expectations. Once the waste escapes the bin it belongs to no one and everyone.

Relationships

This related to how the artists approached and employed waste commonalities and differences. Their shared methodology of storing and repurposing the by-products of their creative material practices to inform an economy of visual language.

Waste is translated through: assemblage, moulding and casting (Matthias); deconstruction and reconfiguration (Darbourne).

Matthias's storage of waste is haphazard; kept in numerous carrier bags, there is no clear catalogue system. Collections of master moulds, wax copies, blown glass components accompany the waste items. Some indiscriminate by-products of making, such as excess plaster pours, are bagged and labelled.

Darbourne is methodical, all soft toys are washed then stored in containers to keep the materials clean. All clothing is removed, any leftovers, synthetic fur, plastic pellets/beads, and stuffing are catalogued and kept.

By collecting abject objects from 'transit points' of repulsion that have negative historical, societal and cultural associations with disposal and expulsion, both artists recognised that through the process of salvage and recuperation objects shift in value as the 'use time' is extended. Stuart Haygarth follows similar principles of amassing waste items and states that 'work is as much about the process of collecting and collating materials as the elevation of these materials to objects of value or beauty' as evident in Mirror Ball, 2009, made from over 300 smashed car wing mirrors presented as a dystopian disco mirror ball (2009).

Metaphors

The associated narrative(s) of waste item(s) and their connections with time, value and the corporeal were already evident in the work of both artists. And there were a number of interwoven theoretical ideas running throughout the collaboration which allowed for a smooth transition to a joint creative identity that could explore and expand the metaphorical visual language.

Merleau Ponty describes the phenomenological human experience of the material world, 'to look at an object is to inhabit it and from this habitation to grasp all things in terms of the aspect which present to it' (2010, p.79) and 'Thus every object is the mirror of all others' (ibid).

The reading of encounters of the material world as defined by Ponty in combination with Douglas's theories of half identity are fundamental to the artists' creative practices particularly when considering the waste objects. This understanding can be expanded to include displaced identity, reconfigured identity, and doubling of objects that are associated with Freud's understanding of the uncanny. 'It may be that the uncanny [the unhomely] is something familiar that has been repressed and then reappears, and that everything uncanny satisfies this condition'. (Freud 2003, p.152).

Time and narrative is evident in the inherent wear and tear of chosen found-objects; they are bruised and battered items that show the effects of labour or love such as old vacuum cleaners filled with debris, or food stained toys.

The value and status of waste could be elevated through: a change of context, location, associations with other materials, and the care and consideration of the assemblage. The moment the waste is removed from the site of disposal and placed in a different context, on a workshop table, its identity starts to shift from discarded to rare item. Its 'use time' is recalibrated. Artist Gavin Turk replicates abhorrent discarded objects, such as bin bags full of rubbish, in bronze and meticulously paints them to become hyperreal simulacrum. Turk said,' There is a provocation around value in presenting people with something they instinctively think has little or no value, and in inviting them to look again to find meaning, importance, and relevance. To re-attribute value is to redefine how value is generated.' (2022)

Corporeal dislocation and anatomical references are features of both artists' work. In the hands of Matthias, sacs and tubes from vacuum cleaners have associations with intestines and lungs; for Darbourne, parts of soft toys are reconfigured, becoming subversively suggestive of anuses or reproductive organs.

Project Intentions

The artists wanted to share and experience one another's creative methodologies and individual visual languages. The collaboration was an opportunity to challenge existing norms and to expand technical, material and conceptual knowledge to create 'a third artistic identity superimposed over and exceeding the individual artist' (Green, 2001, p.179).

There were questions about whether individual authorial signatures would be retained, or whether visual conflict would be created, or one artistic identity would prevail, or whether both identities would become subsumed and a new identity emerge through the collaboration.

The artists approached the entirety of the project with curiosity, keen to gain insight into the modus operandi of the collaboration itself by analysing both individual and collaborative methodologies. Collaborative working was familiar to both via prior management and technical research projects, but neither had worked on such a personal collaborative project. 'One expects new understandings of artistic authorship to appear in artist collaborations, understandings that may or may not be consistent with the artists' solo productions before they take up collaboration projects.' (Green, 2001, p.x)

Due to the nature of the research time, making was sporadic. During these intensive periods the artists had to reacquaint themselves with multiple unfinished pieces and piles of waste, this gave the appearance of mess. However, the methodology was, in fact, more orderly and circular in nature.

In her book discussing play artist Elly Thomas described Palozzi's studio and creative process, 'It was the mess - the open relationship between the items - that was so important to their usefulness. The mass of material was continuously on the move within the artist studio. Paolozzi himself described how this shifting landscape was the generative source from which all his work sprang. (2021, p.8). This fluid approach resonated with Matthias and Darbourne.

The artists required flexible ways of recording their research activities. They used video, photographs and a roll of lining paper, rather than a sketchbook, this allowed them to move through time filling in gaps and recording alternative solutions.

Construction and Composition

From the collections of waste the artists chose the broken car wing mirrors (Matthias), onto which they built a framing device of legs, ears and arms from soft toys (Darbourne), in an arrangement inspired by traditional gilded frames. They responded to the cracks in the mirrors wanting to extend them beyond the frame; the cracks provided a rhythm, a texture and mimicked the fur.

It was important that construction methods were integral to the creative identity of the outcomes and provided innovative solutions. Drawing on prior experience with mixed media assemblages was advantageous, however the combined material libraries presented the challenge of new construction methods. Latex was used as a transitional material, hiding and softening junction points between planes. This approach developed into a series of iterations of mirrors and framing devices.

Additionally, concrete was explored as a way to add weight and counterbalance to capture and solidify negative spaces. Seams, stitches and the textures of the interior fabric of the dismembered soft toys became mummified, the outcomes uncanny and abject. This process combined Matthias's knowledge of model and mould making with Darbourne's understanding of pattern cutting. Kristeva's theories about the causes of abjection inform understanding of the work. She states that 'It is thus not a lack of cleanliness or health that causes abjection but what disturbs identity, system, order. What does not respect borders, positions, rules. The in-between, the ambiguous, the composite'. (1982, p.4)

The artists recognised that this collaborative work was/is situated on the boundaries of craft practice, if craft is commonly defined as the pursuit of technical skills/excellence and the acquisition of tacit knowledge. Matthias and Darbourne have a repertoire of specialist technical skills and material understanding, but their motivation was to explore concepts. Skills were a means to an end as Sennett highlighted in his seminal book, The Craftsman, 'As skill progresses it becomes more problem attuned, at its higher reaches, technique is no longer a mechanical activity; people can feel fully and think deeply what they are doing once they do it well' (2009, p.20). Both found the resource of waste liberating, it was unconfined by technical etiquette.

In contrast to the perceived 'sloppy craft' nature of the disparate and tricky material assemblages the artists recognised that the fixtures and fittings, to mount or stabilise the compositions, needed to be precise, integral and functional. Unlike Gavin Turk's nonchalant display of Cracked Transit Mirror, 2022, a shattered wing mirror stuck on a gallery wall. The artists outsourced the metalwork to a metalworker whose skills were instrumental in realising their ambitions; resulting in a traditional hierarchical relationship between artist and fabricator.

Results

In this section of the paper the artists will discuss some of the outcomes of the collaborative research to date, with a focus on outputs that exemplify the research trajectory. A series of five 'Imaginary Order' wall pieces were produced alongside three plinth based sculptures entitled: 'Abject Bear:Glitzy Mirror', 'Vanity Mirror' and 'Currently Untitled'.

The title 'Imaginary Order' derives from psychoanalytic theories of Jacque Lacan that describe 'The fundamental narcissism by which the human subject creates fantasy images of both himself and his ideal object of desire,' (Felluga, 2015) it closely ties with Lacan's theorization of the mirror stage of an infant's development when they first experience the self as a unified whole by looking in the mirror (ibid). His work re-conceptualized Freud's theories of the unconscious and the primary narcissism of a child's psychological development.

By using shattered wing mirrors, the image of wholeness that constitutes the ego became shattered or distorted or challenged or redefined. The artists wondered if the metaphor of the broken mirror and resulting visual complexities were a reflection of the complexities of the collaboration. They related the doubling aspect of their collaboration with the use of mirrors that symbolised, in some respects, the threshold between oneself and the other. They were also trying to order the waste to find a way for their two egos to create a third entity of imagined order.

The Imaginary Order series is suggestive of collisions, omens of bad luck. The car is a protective shell, offering freedom, upward mobility and status. Soft toys are sometimes displayed on parcel shelves, feminising the masculine veneer. Within the work, the child-like materiality of soft things provided a counterpoint to the repellent, dangerous surfaces.

Imaginary Order #I (Fig. 3) differs in construction and personality from the rest of the series; it is a sandwiched/double rearview mirror which is defensive, mollusc-like in nature protecting a soft centre. This piece creates multiple images of itself and the viewer. The fur is enclosed and fills cavities in the broken mirror rather than lining an aperture. The work has an internal landscape. The other 'Imaginary Order' pieces are formulaic in construction, made using wing mirrors and are comparatively extroverts, the toy limbs expanding the mirror borders.

Imaginary Order #II and #III (Fig. 3) have similar compositions with furry limbs positioned as asymmetrical framing devices. Time was spent deciding on the 'correct' proportions and compositions through photographing multiple permutations.

Fig 3. Matthias, G. & Darbourne, R. (2024) *Imaginary Order #I, #II* and *#III*

Imaginary Order #IV, (Fig. 4) captures and exaggerates the journey of the crack, almost as a form of semaphore or expanded pulse, as a minimalist composition.

Imaginary Order #V (Fig. 4) is fleshy and plump. It has a clear front and back duality, the brown fur referencing bodily functions and waste expulsion. The toy is protective of the mirror that it is framing. The piece is absurd, resembling a road kill splat.

As the series evolved the synthetic materials became more garish in colour; this defined the personality of each piece, the outcomes more flamboyant and kitsch. Each mirror had a metal bracket, the wall plate was a reduced shadow/silhouette, creating a double in the distance. This was an aesthetic decision unifying the front and back of the piece.

Fig 4. Matthias, G. & Darbourne, R. (2024) *Imaginary Order #V and #IV*

'Abject Bear, Glitzy Mirror' (Fig. 5) represented a collision of creative identities; the impact or imposition of aesthetics on one another. It provoked conflicting emotional responses. It has a zoomorphic quality that is endearing but also abhorrent. There are some uncanny aspects, the toy is dead, and is now the antithesis of a transitional object.

Matthias: I embalmed one of Darbourne's teddy bears by filling it with concrete, creating bulk and deformity, unpleasant to the touch.

Darbourne: I took one of Matthias's dirty, smashed wing mirrors and gave it a veneer of cheap glamour with the addition of the clean brown fur and some padding, becoming 'all fur coat and no knickers'.

Matthias: For me it goes against some of my aesthetic sensibilities which makes me want to reject the piece, however, I can allow it because it is ours.

Fig 5. Matthias, G. & Darbourne, R. (2024) *Currently Untitled* and *Abject Bear: Glitzy Mirror*

'Currently Untitled' (Fig. 5) is the permanent name for a piece that is suggestive of a state of flux, the components could be re-presented in a different format. It comprised two precariously stacked ceramic sink pedestals that house a ridiculously small embalmed furry plug, an 'objet petit a'. From the side view this plug is penetrating the pedestal void, from the front it is a furry, fleshy object suggestive of the labia minora filled with concrete. The bone-like ceramics are elevated, the normally unseen interiors are now on display revealing their full grubby horror. The metal rod extends the ceramic form in a linear way, as an antennae, weighted with concrete it precariously puts the stack under tension. The assemblage underwent a variety of compositional arrangements and became the largest piece to date, occupying over two meters in length. It was the last piece to be completed and illustrates future collaborative directions.

Discussion

The Collaboration

'There was me, there was you, there was my waste and there was your waste and this created a vocabulary that we worked with'. Matthias and Darborne

Their catalogues of waste were extensions of their lived experiences and they found a shared narrative that encapsulated the nostalgic, the corporeal, the uncanny, and the abject.

The artists questioned if they had successfully 'created an authorial character exceeding the identity of two collaborating artists' (Green, 2001, p.179). There was a merging of materials, concepts and visual languages that would not exist without the collaboration, and ultimately an authentic third creative identity was established. As identified by silversmith, David Clarke and fine artist/bookbinder Tracey Rowledge when discussing their fifteen year collaboration; "We make together what we are not able to do individually, and the collaborative process allows us to discover new materials, form, scale and subject matter." (2024).

There were the usual creative wrestlings with materials, objects, visual relationships and multitudinous possibilities, as the artists responded to one another's 'what if scenarios'. The playful exchanges were non-combative but the creative process was, at times, a battle. The resulting hybrid artefacts combine opposing aesthetics and hallmarks of the waste materials and subvert material hierarchies and value structures, waste was repositioned, transitioning from non places to a gallery setting, extending its 'use time'.

The creative process generated waste in the form of material offcuts, by-products, all of which were kept and expanded the evolving material libraries. The collaboration was not explicitly exploring the issues around sustainability, however these concerns were evident within the project and could be discussed in the future.

The collaboration is ultimately built on trust and respect, which facilitated the use of one another's materials without fear of plagiarism or transgression of creative identities.

Exhibitions

Imaginary Order: There was me, there was you, there was my waste and there was your waste… was exhibited in Project Space One (PS1), at Arts University Plymouth (AUP) as part of the Making Futures Conference on the 17th-19th October, 2024 and remained in situ until the 23rd October 2024. The exhibition was listed in the Plymouth Art Weekender event. The audience comprised conference attendees, AUP staff, students and the general public.

Prior to this exhibition, Imaginary Order #I and #II, were exhibited at Polyphonous 2024:

Whispers and Cries, Darbourne's ongoing exhibitions project with Professor Jivan Astfalck, at Studio Gabi Green, during Munich Jewellery Week, March 2024. The audience comprised international jewellery artists, students, collectors and academics.

In both instances audiences expressed pleasure in seeing such unorthodox material combinations and waste aesthetics. The absurdity and playful sexual innuendo within the work were commented on with humour and intrigue.

The collaboration is still in its infancy and the artists are keen to work on a larger scale. Imaginary Order has the potential to become a commercial limited edition series, if displayed in quantity, the artists could exploit the relationships and negative spaces between the pieces.

Personal Impact

As part of this PS1 exhibition the artists also presented personal work that had evolved during the collaboration.

Matthias included two new pieces, Clean-Up-Workers XIII (Deluxe Series), an extension of an ongoing series, and an entirely new assemblage entitled 'Dual Shift Boot Retainer'. Both pieces built on existing narratives of combined mechanical and corporeal associations that expressed dis-ease. The main impact of the collaboration on Matthias's artistic identity was the expansion of her material and technical library with the introduction of soft fabrics and toy remnants. 'Dual Shift Boot Retainer' (Fig.6) was inspired by the convoluted intestinal forms revealed through the dismantling and reconfiguring of a Pink Panther soft toy from Darbourne's collection. This presented numerous structural challenges, trying to combine blown or cast glass with flexible materials, and was resolved with internal armatures. Other contemporary practitioners such as Zac Weinberg and Anna Mlasowsky combine a broad range of materials, but the use of fabric plays a secondary role rather than a structural element. Matthias has no devotion to materials and continues to treat them all with equal value, which goes against the impetus of the contemporary art glass arena.

For Darbourne there were a number of positive impacts on her practice, the most significant being the opportunity to work on a larger scale and focus on work that was not sited on the body. Darbourne made one suspended piece for the show using a piece of broken sink from Matthias' archive which was lined with gold leaf and rimmed with brown fur, expanding the visual associations with orifices and reproductive organs. Structurally it was reminiscent of a large necklace. At the commencement of the collaboration, both artists agreed to keep all material by-products; this resulted in a completely new series of jewellery using leftover bits of string, cotton and coloured latex (Fig. 6). This work sits within the field of Art Jewellery and has proven to be commercially successful.

Fig 6a. Matthias, G. (2024) *Dual Shift Boot Retainer*.

Fig 6b. Darbourne, R. 2024. *Colour and Latex*

Conclusion

The collaboration is still in its infancy with both artists keen to continue to explore its nature and potential outcomes and opportunities. The writing and delivery of the conference presentation and co-authoring of this paper were extensions of the creative methodology, a process of shared input and editing until an outcome was reached. Agreement was achieved when both parties were 'satisfied'. However, it is difficult to pinpoint precisely how this happened and requires further analysis in order to understand the full impact of doubling to achieve a third creative identity.

The whole process was challenging but also supportive. Both artists have extended their theoretical knowledge, there are incomplete pieces to finish, potential to expand the scale of the work; and new exhibition opportunities.

By defining waste comprehension and usage under the categories of Materiality; Place; Relationships; and Metaphors the artists recognised that they created a method of compartmentalisation that became restrictive. The artificial separation of strands of research was effective for the generation of original thinking but when it came to unpacking these ideas the artists found that the theories and creative responses were much more intertwined and complex than these headings allowed for.

Art Historian, Kim Grant encapsulated the key components of creative process, 'Instead of viewing art as a cognate for an object, process extends the concept of art to include the object as one point in a complex web of intersecting activities, comprising the artist's process of creation, the object, and the multitude of responses to that object' (2017, pp.11-12).

To conclude, there were the artists, the waste, the making, the myriad of responses, the relationships of waste to place, the process of doubling, and the experiential learning of collaboration.

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Fig 6b. Darbourne, R., (2024). *Colour and Latex*. Photography Rod Gonzalez: Plymouth

Decoding Crafts – the digital transmission of tacit knowledge and material expertise

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Keywords: Tacit Knowledge, Skill, Digital Transmission

Introduction: Summary overview and relevance

As part of our tangible cultural heritage, historic objects play an essential role in the construction of our social memory, thus their preservation also preserves our collective past. Objects have different meanings and uses for different individuals and communities. Research on the history of objects proposes to reflect on "how persons make things and things make persons" (Tilley et al., 2013).

Technical art history was recognised in the last decade as a new field of research which provides detailed information on the methods and materials used by artists and craftspeople. This information is essential for the discovery of arts and crafts production techniques and for locating works within their historical context. The results of technical art history studies open up the possibility for conservators and historians, and also by industry and artists, to rediscover various materials and techniques (Hermens, 2012). In addition, the knowledge gained with these studies may play a major role when establishing the value of an object. Values give significance to some things over others and thereby transform some objects into heritage. The value of a work has a great impact on how it is preserved and what care and treatment it receives, just as a perceived lack of a value can lead to poor preservation (Avrami et al., 2000).

The research of production techniques must involve complementary methodologies: recipe investigation, physical reconstructions following written recipes and material characterisation. This multi-analytical approach is being followed at NOVA FCT in several fields of study including medieval illumination, nineteenth-century paintings, glass and glazes among others (Melo et al., 2016 , Vilarigues et al., 2020).

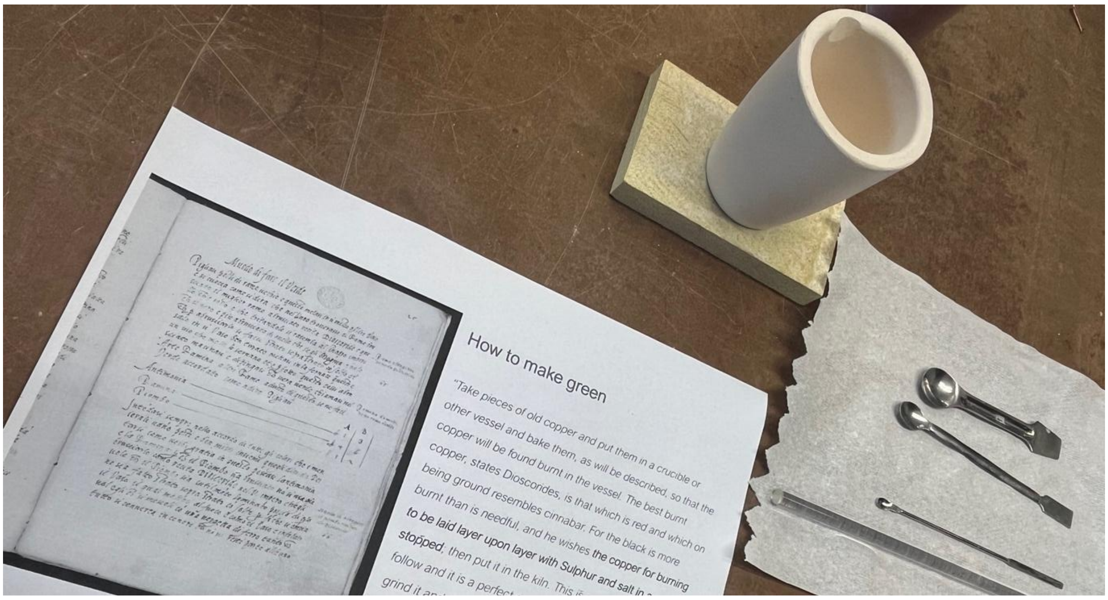

Fig 1. Quinn, et al. (no date) How to make green – demonstration during CRAFT train the trainer's event Wiessensee Academy of Art.

Historical written sources often include step-by-step instructions, providing information on making processes as well as the materials and equipment used, including tools for shaping, mould production and furnaces. Furthermore, recipe books are often critical translations and may contain commentaries, annotations, and additional recipes from previous treatises (see for example for glassmaking information at (Moretti et al., 2013).

The question that now arises is how to expand the impact of this research, not only to the conservation and restoration sector but more generally to the preservation of tangible and intangible heritage associated with skills and know-how. This research includes not only historically used materials but also techniques, associated gestures and their transmission. This demand what may be called gesture knowledge, defined by Heinz Otto Sibum as "the body of information, understanding, experience, and skill required to produce gestures effectively in a given context of use" (Sibum, H.O., 1995, Stud. Hist. Phil. Sci., Vol. 26 (1). pp. 73-106).

But how can one tackle the study of historical know how? Skill and tacit knowledge are determined not only by the used materials but also by the human interaction with objects and each other. We can approach these studies by designing and building historically accurate materials, replicas, performing techniques and use of objects, along with historical, archival exploration of the world in which these historical experiments were developed. These steps may help us to reconstitute tacit dimensions of past practices that were taken for granted, kept secret, and therefore not written down.

Is intangible knowledge transferable? How can we make embodied knowledge accessible to all? In the crafts these questions are of paramount concern as we slip from the age of Human Intelligence (HI) into the age of Artificial Intelligence (AI). How to transfer centuries of knowledge and experience to a new generation of conservators, researchers, crafts people, artisans and designers if AI, robots and 3D printers can just do it for you?

Tacit Knowledge, described as ‘knowing more than we can tell’ (Polanyi, M, 1967) is the hard-earned embodied knowledge gained through personal experience, something we might describe as expertise, which in turn can be understood to be the experience of having done something for a really long time that you become really skilled at it. Skill is acquired through trial and error or repetition, which involves a lot of time which we call practice. Ingold describes this as the art of inquiry (Ingold, T, 2013), where crafts people allow knowledge to grow over a long period of time, with each new bit of knowledge being assimilated, tested, and integrated into the toolkit. Finally, technology is the tool, not the output, meaning what it offers, what it can do for us, not the star of the show.

Fig 2. Siburn (1995) *Gesture Knowledge*. Evidenced through the demonstration of embodied knowledge at UMPRUM Academy of Arts, Architecture and Design, Prague

How do we decode these complexities for sustainable future proof disciplines? This paper argues for a recognition that these new technologies are not a threat but a new opportunity to valorise and sustain centuries old savoir faire. We propose that machine learning is actually a requirement, as in the machine needs to learn from the human, that it cannot simply watch and then do. Furthermore, we propose methodologies for collaborating with technology, to unpack tacit knowledge, to preserve expertise and make it accessible, transferable, and learnable.

Traditionally, research in craft production focused on the materials and techniques required to form objects, the associated gestures and their transmission were considered the realm of anthropologists. However, 'the complexity of skills and forms of mastery developed in real time performances' what Siburn calls Gesture Knowledge (Siburn, H, O. 1995) require the incorporation of another layer of knowledge to encourage machine learning between crafts person and co-bots, and crafts person to novice, resulting in the preservation and transmission of expertise between machine and human.

The design and building of historically accurate materials, replicating forming techniques and use of tools, along with archival exploration of the world and context in which these historical experiments were developed, allow us to unlock these steps, and may help us to reconstitute the tacit dimensions of present and past practices, from which hybrid practices, combining tacit knowledge of centuries of material expertise with innovations such as additive manufacturing, are essential. The acquisition of Material Intelligence (Adamson, G, 2018) is essential to grounding intangible cultural knowledge towards a future of digitally enhanced crafts, were crafts person and machine work together. David Pye (1968) proposed the idea of Workmanship of Risk (craft) and Workmanship of Certainty (manufacturing), we eagerly accepted this view as a valorization of crafts people constantly working on the edge of failure and a recognition of the limiting industrial paradigm of replicable production. However, Adamson highlights that crafts people have always worked to mitigate risk in the making, to refine their process to a point where any risky or serendipitous action has been achieved in highly controlled way, utilizing *know how* and tool making.

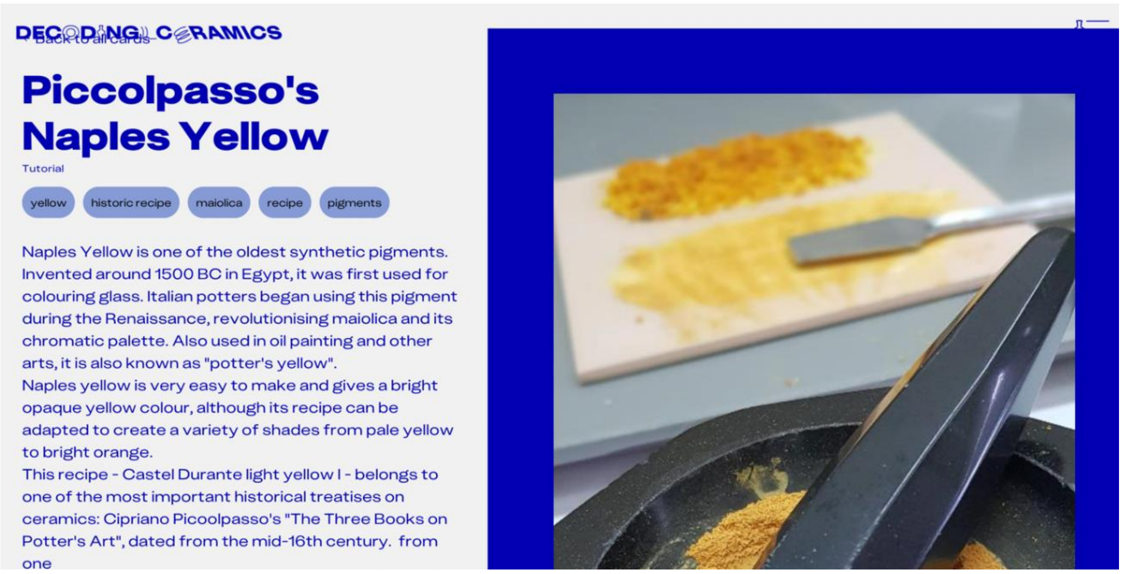

Fig 3. Decoding Ceramics (no date) Creating historically accurate recipes using Decoding Cards, on the Decoding Ceramics Platform.

Higher Education Institutions (HEIs) have become the de facto custodians for traditions of skilled artisanship, whilst the Heritage Craft industries face a potential decline of skills in the face of economic and technological developments. Consequently, the educational institution which has become the home of the more traditional craft practices and a laboratory for the experimental and innovative combination of these traditional technologies with the tools and methods of industry 5.0. This crafts ecosystem is fragile. Educational departments across Europe are run by a small group of experts, with a tiny and dedicated workforce keeping hundreds of years of local savoir-faire alive, through a resource heavy, time-consuming specialist education, which wrestles with the principle of Troublesome Knowledge (Meyer & Land, 2006), that things are difficult and take time to master and more importantly relies on a sense of Legitimate Peripheral Participation (Lave & Wenger, 1991), where novices are taught by experts until they in turn become teachers.

Roger Kneebone (2020) proposes that a consistent thing about experts is that they all claim to have more to learn. There is a need to make access to specialist forms of material knowledge open and fit for the purpose of transmission, to record and elucidate embodied and tacit knowledge, usually gained through experience and repetition, with the intention to valorise and sustain craft knowledge and practice into the future. Accepting that people learning together is essential to sharing of knowledge, John Seeley Brown (2008) tells us that 'Understanding of content is socially constructed through conversation about that content and through grounded interactions especially with others' this is where social media becomes the tool de jour allowing people to share and discuss their learning in almost real-time.

This paper explores these factors whilst focusing on ceramics, it proposes scalable, transferable methodologies across other material led disciplines, building on the extensive mapping of craft techniques developed within the Erasmus+ Decoding Ceramics research. Decoding Ceramics articulates the imperative to save expert knowledge and valorise traditions of skilled artisanship across the world for a sustainable future discipline. Decoding Ceramics is a new network and open educational resource that maps ceramic knowledge across makers studios, workshops, manufacturers, research centres and universities. It assesses the salience of practice to place, builds a visual and oral record of specialist processes and techniques, leveraging digital technologies to decode tacit knowledge and effectively share this knowledge across the teaching and learning network to ensure ceramic practices are relevant and accessible to future learners, teachers, craftspeople, and enthusiasts.

Methodology: Methods, stages, and techniques

The Erasmus funded CRAFT Activating Pedagogy for Ceramic Futures project brought together consortium of partner HEIs including University of the Arts London, Weissensee School of Art Berlin, KHiO Oslo, UMPRUM Prague and NOVA University Lisbon (supported by selected associated partners) with the express intention of having a discipline overview across Europe. Taking the position that is both prescient and crucial to map ceramic knowledge across Europe, focusing where possible on endangered knowledge and assessing the salience of practice to place, building a visual and oral record of specialist processes and techniques, and key to this, develop methods to effectively share this knowledge across the teaching and expert network to ensure heritage crafts skill are relevant to future practice. The research had three specific aims:

- Mapping ceramic places, skills, processes, technologies, intangible knowledge, and training practices for making ceramics.

- Developing pedagogical approaches and innovative teaching methods to teach ceramics to sustain the future of the subject.
- Developing skills resources, offering repertoires of knowledge and practice for making ceramics

The project delivery methodology relied upon critical and creative thinking, participatory methods, problem and challenge-based learning approaches, design for transformational practices and collaborative methods.

The project implementation comprised the following interrelated phases that partly overlapped in timing to allow for ongoing review, assessment and fine-tuning of intellectual outputs based on the project's activities:

Phase 1: mapping

Desk research was initiated to identify clusters of excellence and practice within the diversification of production (ateliers, companies) including cultural, historical, and place-making factors. A common framework for data harvesting was designed, including a set of criteria to define expertise (technical and tacit knowledge), in order of importance for (future) ceramics: critical, essential, and important. This approach mapped sector knowledge and reached into Communities of Practices, investigating where the knowledge/training and facilities where located.

The interactive map enables the viewer to dig deep into the subject linking via skills, region, materiality etc. Cross-cultural and interdisciplinary connections enable the user to access information beyond the obvious or immediate to unlock expertise.

Phase 2: pedagogical approaches

Qualitative methodologies were applied, including focus groups, desk, and action research methodologies. Mapping of pan European teaching methods utilised an online tool for digital collaboration (Miro) was initiated by KHB and filled and evaluated qualitatively by project partners. Teaching Methods from other institutions were tested with students within different curricular structures and very varying prior skill sets and resources.

Fig 4. Quinn, et al (no date) Miro sharing of knowledge and expertise by institution – a fundamentalmethod to establish capacity for sharing of knowledge

Phase 3: materials productions

This phase is part of the work as a synthesis of local researchers and new didactical approaches. A template for video recording was created, including a description of unifying features such as script, introduction, technique introduction, tools' introduction, material specification. Development of the Tool library specification of necessary tools and equipment.

Phase 4: creation of the open educational platform Decoding Ceramics

This platform includes innovative pedagogy and curriculum mapping encourages the sharing of best practices between partners and establishes points of intersection for collaborative teaching approaches which point to a new distributed open-access form of education.

Main Results

The project led to a prototype map of makers, studios, manufacturers, museums and research centre's, identifying a particular skill or process that may be uniquely applied in context or similar to other places with a different approach or final output. From this first sweep of Points of Interest (POI), partners explored correlation or connection of processes between different locations. The groundwork enabled to survey where the endangered knowledge and expertise was located and, more importantly, the mapping exercise alerted to a fragmented discipline, with a lot of repetition, and areas of threat, due to many factors outside of the discipline.

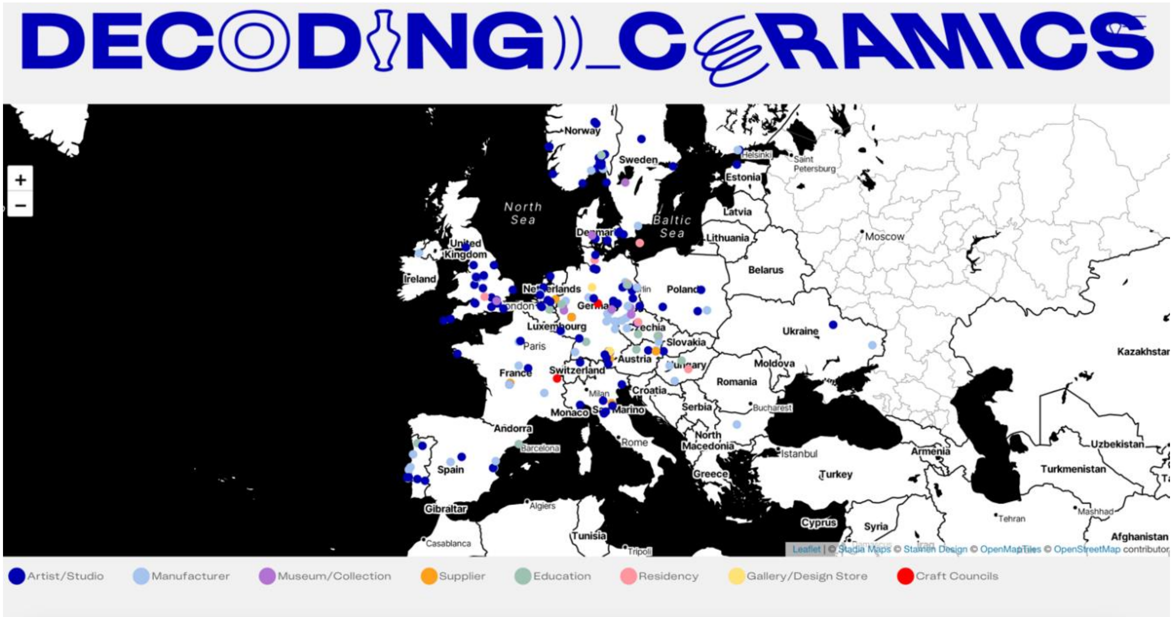

Fig 5. Decoding Ceramics (no date) Mapping process, skills and endangered knowledge across Europe.

Consequently, a key aspect of the network was the sharing of knowledge and exchange of teaching approaches. Partners identified the imperative to capture and share and endangered knowledge and make expertise open to all. What is the most effective method of demonstrating this technique for the learner? How do you teach experience if Polanyi tells us we know more than we can tell? Ingold counters this position with 'we can tell of what we know through practice and experience, precisely because telling is itself a modality of performance' (Ingold, 2013), essentially proposing that we have to start somewhere. A series of 'train the trainers' workshops explored methodologies on how to unpack tacit knowledge and expertise for other teachers.

The intention was not to teach the technique or process, after all we were performing the demonstration to expert educators, but to explore how best to communicate the technique or process in a way *that it can be learnt*. How to make the troublesome knowledge accessible and learnable to all. How can we build a skills repertoire that can capture endangered knowledge and make it available to all and provide a form of technical support and guidance that come from working in proximity with a teacher.

This led to a period of developing experimental approaches to the pedagogy of craft by back filling the knowledge required to learn and adopt the endangered knowledge identified through the mapping exercise.

The obvious answer is to create video demonstrations; however, YouTube and Vimeo are proliferated with teaching videos that reinforce the hierarchy of knowledge with a well-meaning expert, making something really difficult look really easy, running counter to the idea of decoding tacit knowledge. There was a need to decode the expert demonstration by creating augmented video instructibles that enabled people to replicate the process and learn through doing. Gesture capture and video annotation were utilised to add layers of understanding and make the tacit explicit. A new augmentation tool 'Motion Notes' enabled the Integration of layers of meaning and knowledge to the video (ref[a]). The purpose was to give the educator the means to communicate everything that was happening to the viewer to illustrate what was being said by enhancing the demonstration experience.

Fig 6. Decoding Ceramics (no date) Augmenting video demonstration to reveal hidden embodied expertise.

Decoding Cards were designed, to contain step by step processes, tool and material lists, health and safety requirements, other references and complimentary or next step processes as well as the augmented demonstrations. The Decoding Cards represent new ways and forms of teaching and dissemination of knowledge towards a more agile and open sharing culture. The teaching cards decode traditional tacit craft knowledge and seek to communicate both traditional and emerging ceramic knowledge to cope with the shift from traditions of subject discipline delivery. For example, the use of motion capture and video annotations are promising tools to make gestures and tacit knowledge explicit to the learners and will transform the way to access and decode specialist craft knowledge.

Finally, a platform www.decodingceramics.org was developed to make the research openly accessible to all, which encompasses.

- An interactive map enabling access to datasets and providing information on ceramic artists or studios, relevant locations, and additional information on the specific techniques that are developed in each place. A User-friendly navigation tool allows the user to dig deep across the map linking via skill, region, materiality etc. The possibilities this approach affords the audience are only now being understood and will require further work to make it effective as a learning tool, that might guide the viewers curiosity through levels of aptitude. The map captures the ceramic intangible cultural heritage, expert knowledge disappearing skills and techniques and connects the points of interest with relevant teaching approaches, video tutorials, step-by-step, kit lists and health & safety. The depth of connection from place to teaching approaches makes the platform a powerful teaching and learning tool.
- Decoding Cards, a compilation of teaching cards proposing: a) Activities for a range of

approaches, from basic knowledge acquisition such as how to prepare clay, introduction to glazing, throwing, hand building and extruding, to more advanced cross disciplinary approaches such as CNC milling, of moulds and 3D printing ceramics; b) Lectures; such as what on earth is clay or Glazing using the grid methods, c Projects e.g. building a community kiln, BIG, making large scale sculpture and skilling up, introduction to basic manufacturing techniques, d) Tutorials. Each card contains an introduction, Step-by-Step instructions, a video, information on materials, tools and level of skills needed and time, recommended next steps and further activities. Each card includes as well as health and safety information and linked Point of Interest from the interactive map, showing exemplar places custodian of tradition, techniques or know-how. The cards are a powerful tool which helps to link the mapped expert knowledge to individual learning experiences in acquisition of a large variety of skills and embodied knowledge as well as a contextual framework. The cards are interactive learning resources that are freely accessible through the Decoding Ceramics platform.

• A series of experimental videos used a novel video annotation tool to design innovative demonstration videos. The tool is a result of in-depth work to devise both the correct methodology and approach on how to annotate for the most effective communication of tacit knowledge and craft skills. The Video Annotator tool, available through the platform enables users to experiment and prepare their own annotated teaching demonstrations. The new annotated video demonstrations have the potential to push the design of innovative tutorials far beyond the existing 'showing and talking' approach that proliferates at present. The development towards video demonstration that embeds other layers of decoded tacit knowledge into the video, using diagrams and technical drawings to explain otherwise hidden details will transform access to specialist knowledge. These videos can be found on the YouTube channel *https://www.youtube.com/@DecodingCeramics*.

Discussion: Contribution and impact

The Decoding Ceramics partnership

• established a new international network of ceramic educators and an open knowledge exchange platform for the development of new pedagogies and approaches to make subject more transdisciplinary and sustainable.

• facilitated an increased capacity for experimentation and prototyping within principles of heritage and future manufacturing.

• impacted on teachers/trainers/practitioners by providing the context and opportunity to develop new transformative pedagogies, building and participating in transdisciplinary projects with like-minded departments for the fostering of a shared community of practice based on open knowledge exchange, teaching methodologies and curricula.

• empowered the ceramics education community by providing access to an open education platform, including an interactive map of skills and expertise as well as pedagogical approaches and teaching methods through decoding cards.

Decoding Ceramics established new forms of experiential pedagogy through shared curricula and the development of transnational and cross-disciplinary modules open to all partnership members. The strong focus on interactive use of the platform (filtering by topic/cross-linking points of interest and techniques/the possibility for the user to generate an individual teaching path) will lead to a long duration of stay on the platform and deep engagement with its content. Users are welcome to contribute to the map and teaching tools after the project's end and the platform is intended to grow continuously.

Decoding Ceramics has instigated an expansion of Teacher/Trainer knowledge through shared teaching repertoires. The partnership has increased interest in studying Ceramics across Europe, as evidenced at UAL where applications have increased by 100% in 2022 and 60% in 2023. Decoding Ceramics benefited the partners by opening trans-disciplinary research, opportunities; increasing awareness and curiosity for faculty and student exchange; reinforcing teaching quality and excellence; and further placing the partners as holders of intangible cultural heritage in the role of subject custodians for the preservation of specialist and endangered knowledge.

How does Decoding Ceramics contribute to the persuasive nascent field of digitally enhanced crafts? What can the rest of the crafts learn from Decoding Ceramics?

It is essential to leverage technology to sustain and valorise traditions of skill and expertise, using the technologies at hand as tools to capture knowledge and unlock learning. Technology is a tool not the driver, however what we are doing would not be possible without certain technologies, gesture capture, video annotation, 3d printing, photogrammetry, and robotics. The Decoding Ceramics methodology is complimentary to other research that uses tools in a more active way, in that it captures the skills, knowledge and expertise, and it supports this development as the research in this area 'does not combine a craft persons direct interaction with the material by using traditional tools simultaneously when using digital technology' (Tvede Hanson, 2023). This repository of skill that decodes expertise is an essential addition to the work of Unfold studio's L'artisan electonique (2010), Flemming Tvede Hanson's digital experimentations in architectural ceramics (2023), Konrad Junger's Material Driven, Digitally Produced, collection (2022); where all rely on embodied knowledge and material intelligence (Adamson, 2019) to drive technological research.

Fig 7 & 8. Tvede Hanson (2023) Exploring 'introducing human–material dialogues', through drawing and co-bots during train the trainers event in Wiessensee Academy of Art

In some way this approach could be considered prosaic, however it is essential to provide the grounding from which digital research can be evolved. There has been a race to adopt new tools, without ensuring that hundreds or thousands of years of savoir faire is safe. An emerging axiom of new forms of practice that you cannot simply press *go* without fundamental embodied material knowledge, interestingly many digital crafts people are learning this the hard way, through productive failure, and troublesome knowledge.

Decoding Ceramics, mission to decode tacit knowledge and expertise, and make it open, useful and free to all, is essential for the programming of a sustainable future discipline that's combines know how and cutting-edge technology.

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Crafting wellbeing: a dynamic collaboration between people, disciplines, and trees.

Kirsten Scott, Karen Spurgin, Jonathan Butler, Prabhuraj Venkatraman, Fred Mutebi, Lesli Robertson.

Keywords: craft-thinking, interdisciplinary collaboration, barkcloth, indigenous knowledge systems, wellbeing

Introduction

Craft thinking allows the material dialogues that take place during the act of making to become methods of possibility-finding. It requires active reflexivity throughout that dialogue, with the willingness to let go of pre-conceived ideas, tools, or techniques in response to listening to what the materials want to say and to the negotiated and novel affordances that emerge (Groth and Nimkulrat 2025, Brinck 2025, Barati and Karana 2019). When repetitive practical tasks are performed – for example, stitching, weaving, knitting - the mind of the maker is able to travel laterally: to tentatively explore conversations with other knowledges and disciplines, glimpse further possibilities and dreams, and to fold these back in through a generative process that disregards traditional disciplinary boundaries (Brinck 2025).

This paper discusses the dynamics of this 'folding in' of diverse knowledges and peoples in a craft-led research project, through the work of the Barkcloth Research Network. It explains how a pragmatic, craft-led investigation into the potential of a radically indigenous, endangered textile for sustainable fashion has evolved into a multi-disciplinary research project with a team that currently comprises designers, farmers, artists, craftsmen, environmentalists, textile technologists and scientists in the UK, US and Uganda. The research demonstrates the potential of craft to assist in resolving complex, wicked problems and advances the role of craft-thinking in brokering new relationships and possibilities between people, disciplines and the more than human.

Problem statements

A disconnect from the natural world has been exacerbated by population shifts to urban areas. This has enabled the systematic plunder and degradation of natural resources - unimpeded and even unnoticed by most of us. There has been an average decrease of 69% in global wildlife populations since 1970 (WWF 2022) and since 1990 global deforestation is already equivalent to the size of Libya (FAO 2020). In 1950, only 30% of the world's population lived in urban areas; today this has risen to 56% and is expected to grow significantly by 2050 (World Bank 2023, UN 2019). Land degradation is an existential threat to the human and more than human inhabitants of the Earth; some consequences of this disconnect from nature are all too clear:

a) Increasing levels of stress and anxiety in city populations may not only be linked to hectic lifestyles, changes to work-life balance, and by the technologies that distract and enthral us, but also to a disconnect from the restorative effects of the natural world (Bell and Ward Thompson, 2014; Grinde and Patel, 2009, Kellert et al, 2017, DEFRA 2024, UN 2019). In 2023, 60% of people in the UK reported experiencing anxiety, 76% stress, and 56% experienced depression (Pindar 2023). Research shows that there are substantial benefits to health and wellbeing gained from spending time in nature – it having a restorative effect on people suffering from a range of health disorders (Kellert et al. 2008, Bell and Ward Thompson 2014, Barbiero and Berto 2021, American Heart Association 2024). Calm is improved and blood pressure decreased merely by touching the leaves and the bark of trees (Putra et al 2018). In addition, walking in forests enables phytoncides—chemicals released into the air by trees—to stimulate the immune system in ways that even prevent certain diseases (including cancer) from forming, as well as to improve our ability to manage stress (Putra et al 2018, Hansen et al 2017, Bell and Ward Thompson 2014, Grinde and Patel 2009).

b) Anti-microbial resistance is a major global concern, set to exceed cancer as the leading cause of mortality by 2050 (Butler et al 2020). It is estimated that between 7-10% of hospital patients will develop health care associated wound infections (HCAIs). Staphylococcus aureus (MRSA) is the most common cause of infection, and has become methicillin-resistant (Butler et al 2020). Most antimicrobial fabrics used in wound dressings employ metals and other synthetic compounds that are reliant on extractive processes and are, therefore, unsustainable. It is vital now to find effective, natural alternatives that might have intrinsic healing properties.

c) Soil biodiversity relates to all the living organisms in the soil that effectively function as a community to provide services that support plant and animal productivity. A complex network of micro-organisms is crucial to soil nutrient, energy and water recycling; to maintaining water quality; to decomposing inactive toxic materials as well as organic matter; and in extracting greenhouse gases from the atmosphere (Tahat et al 2020, Fahad et al 2022). However, soil health is deteriorating rapidly due to intensive human activities, including industrialised agriculture, with associated overuse of pesticides and fertiliser (European Environment Agency, 2023, FAO 2015, Tahat et al 2020). Switching to organic farming is a long and costly process, with farmers experiencing lower yields in the short term. Organic fertilisers are more expensive than synthetic fertilisers too, placing further financial burden on farmers that wish to transition to soil-friendly agriculture (Tahat et al 2020). It is vital now to find locally-specific, environmentally-sustainable, plant-based solutions to improving soil health and to learn from communities that manage this successfully.

These three, diverse but interconnected wicked problems share a potential solution that has emerged through interdisciplinary, craft-led research (Zimmerman et al, 2010): the mutuba tree (ficus natalensis), from which Ugandan barkcloth is made (Figure 1).

Fig 1. The mutuba tree (ficus natalensis).

Fig 2. Bazomazi Paul Bukenya harvesting bark

The Barkcloth Research Network (BCRN)

The BCRN was founded in 2016, initially to explore the potential of Ugandan barkcloth as a sustainable, luxury, fashion textile. As a result of the potentialities that have emerged through craft practice, the network has grown organically, folding in new members and disciplines with richly diverse lenses, knowledges, technical and other expertise that contribute to an ongoing project that continues to reveal exciting new possibilities.

Ugandan barkcloth

> These communities are the repositories of vast accumulations of traditional knowledge and experience that links humanity with its ancient origins. Their disappearance is a loss for the larger society, which could learn a great deal from their traditional skills in sustainably managing very complex ecological systems. (Brundtland, 1987: 114-5)

Barkcloth, or *lubugo* in the Luganda language, has been produced from the mutuba tree by the Baganda people of southern Uganda since at least the 13th century. It has been designated part of the Intangible Cultural Heritage of Humanity by UNESCO since 2005 (UNESCO 2005), and represents an entirely sustainable, traditional ecological knowledge (TEK) system where skilled craftsmen work in close collaboration with trees, with knowledge passed down through generations (Figure 2). It is made from the inner bark of the mutuba tree, which may be carefully harvested annually for at least fifty years without damage to the tree; the bark is softened in boiling water or steam, beaten by a series of ridged wooden mallets until the fibres almost felt as it grows dramatically in size to form a large, relatively soft and pliant sheet (Scott et al 2023, Venkatraman and Scott 2018, Figure 3). It is laid on the grass to dry, anchored by stones, and develops a natural, rich, rust colour. These processes demonstrate utmost respect for the trees, which are tended with great care: checked before harvesting, that their bark is willing to be taken, in the rainy season when they are less likely to be damaged; a sharpened wedge of a banana tree branch is used to prise the inner bark away from the trunk - just strong enough, but also gentle enough, not to hurt the tree - before wrapping the trunk with banana leaves for a day or two while it stabilises - preventing infection and allowing a new bark to begin to grow. The barkcloth processors of Bukomansimbi are living repositories of TEK that demonstrates how to sustainably collaborate with nature (Brundtland 1987).

Barkcloth is symbolic of Baganda cultural identity, having historically been worn at the Bugandan court as a signifier of status, and was an important item of regional trade before imported woven cotton fabrics were introduced in the mid-nineteenth century (Nakazibwe 2005, Venkatraman and Scott 2018). Today, sheets of barkcloth are still knotted over contemporary clothing for ceremonies, worn by the Kabaka of Buganda kingdom, and by political leaders as a signifier of their culture and tribal affinities. However, it is rarely used in clothing today and more frequently appears as burial shrouds because of its anti-bacterial properties – in fact for some, it has become closely associated with death, ritual, or tourist craft. Barkcloth production is endangered due to this declining market and therefore few young people see a future for themselves as bakomazi (barkcloth processers) that might motivate them to stay in their villages and learn this ancient craft. An important mission of the BCRN has been to assist in preserving and promoting this indigenous knowledge system as part of the future heritage of humanity (not as relegated to the past), as it holds clues to how we might live better on the Earth. All knowledge generated from the research is made public and shared back with its community, using a model that the team call Borrowed Cloth: borrowing the cloth, never forgetting who it really belongs to, and returning this knowledge as interest on the loan (Scott 2020). The research in the UK and US has evolved in consultation with key team members in Uganda, and with sensitivity to the enduring legacies of problematic and exploitative colonial histories.

Research methods and results

To investigate the potential of a barkcloth for sustainable luxury fashion, and the subsequent aims that organically have arisen, a highly agile and pragmatic research approach has been used, unfettered by rigid methodology nor bound by conventional timeframes. The research is generative and therefore open-ended, as more possibilities continue to emerge. Qualitative research methods began by thinking through a series of design and making processes (Ingold, 2013). These were supported by field research in Uganda, which included interviews, observation, documentation, filming, photography and listening. Interviews with farmers provided insights into the rich benefits of local integrated farming practices. Interviews with barkcloth processors detailed their collaboration with the mutuba trees and the histories, development and the significance to them of their craft practice. Quantitative experimentation in a textile technology laboratory and a microbiology laboratory at Manchester Metropolitan University defined and measured the mechanical qualities of barkcloth and its unique antimicrobial propensities with startling results (Butler et al, 2020). Each team member brings a different perspective to the project, which are here characterised as lenses.

Different lenses

Kirsten Scott (designer-maker-researcher in fashion and textile systems, and fibres, and Head of Research at Istituto Marangoni London) first began by playing with barkcloth, listening to what it had to say, what it might be persuaded to say, and then expanding and refining this through a series of experiments, samples, sketches, maquettes and garments. Some of the processes were repetitive and even meditative in nature - for example, cutting and stitching fine strips of barkcloth onto a curved barkcloth shape, in ways that emphasised its sculptural form while simultaneously strengthening a garment body (Figure 4). This lengthy process allowed her mind to wander, to consider the ways that curved shapes can reflect or be abstracted from forms found in nature, the potential psychological benefits of this (Kellert et al 2017), and then the possibilities to exaggerate these curves in ways that improved the functionality and distinctive aesthetics of the garments (Figure 4). For example, through excess fabric across pressure-points such as the upper back, or at the elbows, bottom or knees. This conversation with the cloth, therefore, evolved a design strategy that drew on biophilic and biomechanical design theory, crossing disciplinary boundaries and dipping into other knowledges as the cloth directed, to work with the limitations and opportunities that the cloth afforded rather than imposing a pre-determined design upon it. A fluid interchange between practice and theory developed: practice suggesting reading and reading suggesting practice. In this way, a series of luxury garments were made in barkcloth that aimed to demonstrate its value in contemporary luxury fashion. Although some initial design ideas were sketched out, or modelled on a mannequin to start with, the process of making redirected these designs and the scope of the research itself, leading to a reconceptualization of luxury today as rooted in an ability to promote the wellbeing of peoples and planet (Scott et al 2023, Scott 2020). In addition to developing a materials-led, biophilic design strategy for clothing, her research suggests that actually wearing barkcloth may deliver benefits to wellbeing, a hypothesis to be tested in clinical trials: if just touching the bark of trees reduces stress (Putra et al 2018), how much more might wearing it?

Fig 3. Thinking through making, taking on board the results of strength tests, in the development of a biomechanical and biophilic design strategy.

Fig 4. Paul Bukenya with processed barkcloth in its natural colour

Fig 5. Barkcloth jacket using biophilic and biomechanical design strategy, dyed with indigo.

It was felt that the natural rich, rust colour of barkcloth was limiting (Figure 4), so it was important to sustainably develop alternative colours that could be dyed over this – in particular black, as a useful colour in luxury fashion. Karen Spurgin (embroiderer, natural-dye researcher, co-founder of ao textiles, and Senior Lecturer in Textiles at Istituto Marangoni London) explored natural dyes for and from barkcloth. Karen first investigated some traditional Chinese textiles, such as Liang Chou Silk and the shiny silk of the Miao people, to experiment with different surfaces and coatings for barkcloth. Eventually, drawing on medieval tempera recipes, by using egg white and logwood, she created a natural, lustrous, black coating that improves water-resistance and is entirely compostable (Figure 6). However, it was through these experiments that other possibilities emerged - as Karen discovered that barkcloth yields a pigment of its own, that could be used to dye other materials. She was able to extract pigment from barkcloth scraps so that nothing was wasted, in a series of experiments that established the optimal strength of dye solution and the most effective mordants to offer a range of shades of brownish-pinks (Figure 7). Karen tested these in a sheer, layered, silk dress embroidered with threads that were also dyed with barkcloth (Figure 8). As the team began to explore barkcloth's antibacterial properties, Karen was prompted to research Ayruvastra, a 5000-year-old Indian tradition where textiles are used to impart health benefits to the wearer, through the skin, by dyeing them with plants that have specific healing properties (Thakker 2020). This research has potential in bespoke luxury fashion for wellbeing, as well as in sportswear, children's clothing, bedding and in medical use (Scott et al 2023).

Fig 6. Logwood glair coating for barkcloth

Fig 7. Silk crepeline and threads dyed with barkcloth scraps

Fig 8. Embroidered silk crepeline dress – all dyed with barkcloth scraps.

Early in the project, Prabhuraj Venkatraman (Senior Lecturer in Textile Technology at Manchester Fashion Institute) joined the BCRN. He identified that barkcloth's natural and relatively unmediated origin means that its rather coarse, irregular fibre strands can lead to inconsistent densities in a sheet of cloth. Fabric tests were undertaken at Manchester Fashion Institute to assess its performance – including fabric drape, stiffness, surface morphology and tensile strength (Figure 9). The results revealed that it had a stiff texture and poor strength, which are challenges to be overcome. The barkcloth was also subjected to CO2 laser patterning and sublimation printing to incorporate surface patterns and fused with various interfacing fabrics to reduce its stiffness, enhance drape, and increase strength (although these were not sustainable choices). A size 12 female full-sleeve top was developed with the fused barkcloth that offered good drape and its shape and fit were evaluated on a mannequin. Based on these evaluations, he concluded that barkcloth could be developed into further outer garments, but it seems likely that barkcloth - in its natural form - is not viable for use in industrially-produced clothing. However, the luxury sector contains niche areas where connoisseur customers place value on unique, slow craft processes, sustainability and the heritage– and are therefore more open to the non-uniform and distinctive qualities that this indigenous textile offers and the conventional demand for scalability does not apply. Further research is planned with consumers to evaluate barkcloth-based garments for aesthetics, comfort, fit and tactile sensation (Venkatraman et al., 2020). Prabhuraj contributes a scientific approach to the research, that employs rigorous testing to assess the commercial viability of fabrics, which provides useful quality benchmarks. His work highlights some of the technical challenges as well as the opportunities of using barkcloth in clothing, that informed Kirsten's use of stitched strips to strengthen barkcloth garments.

Fig 9. Burst tests at MMU textiles laboratory, to measure barkcloth's strength.

As indicated above, as the project unfolded, interviews with members of the BOTFA community revealed that barkcloth has anti-bacterial properties and thus used to wrap wounds and also bodies for burial. Although this knowledge is widely held in Bukomansimbi, and applied in local first aid treatments, it had not yet been tested in a university laboratory, nor had any test results been peer-reviewed. As Karen had begun to research Ayurvastra for her barkcloth dye experiments, Jonathan Butler (Senior Lecturer in Microbiology at Manchester Metropolitan University) joined the BCRN to investigate and determine whether barkcloth might combat bacterial infections such as MRSA. Initially sceptical, he was impressed by the results of his tests - where a 99 per cent reduction in bacterial viability after four hours was observed when barkcloth was exposed to MRSA; after 24 hours, this increased to a 99.99999 per cent (seven-log) reduction in bacterial viability (Butler et al. 2020, Figure 10). Jonathan's research suggests that the barkcloth causes morphological changes in the bacterial cellular ultrastructure after contact exposure to the fabric material. It was further observed that MRSA cells became irregular in shape, with invaginations, holes and perforations and there was also evidence of extracellular cytoplasmic leakage (Butler et al. 2020, Scott et al 2023), which caused the antimicrobial effect. The active anti-microbial compound/s in barkcloth remain to be identified and this is a current focus of Jonathan's research, but it appears that barkcloth has the potential to be used in wound dressing technology, due to its good porosity, identified by Prabhu (Venkatraman et al. 2020), antimicrobial activity, mechanical protection, environmental sustainability and cost effectiveness, which may expand opportunities for the Bukomansimbi community.

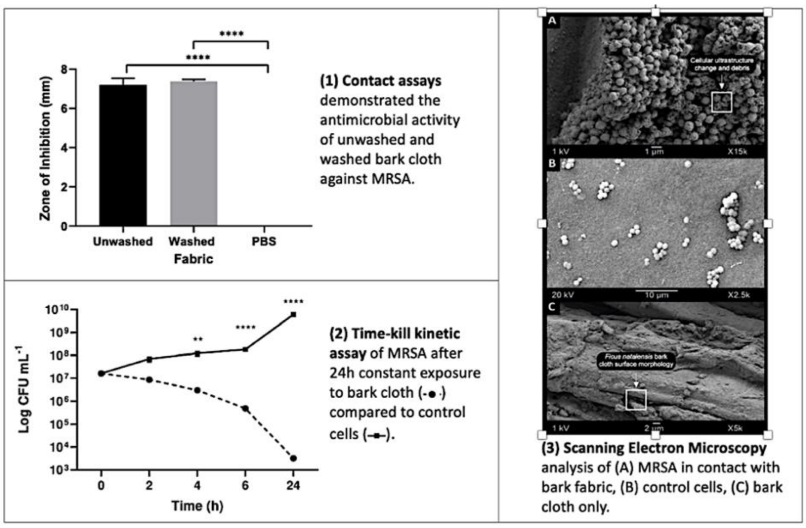

Fig 10. The results of contact assays that revealed barkcloth's ability to kill MRSA.

The Bukomansimbi Organic Tree Farmers Association (BOTFA) was founded by artist, Fulbright scholar and environmentalist Fred Mutebi. Fred grew up in rural Masaka, in southern Uganda, but has travelled extensively – receiving a Fulbright scholarship and showing his art all over the world. His revival of wood-cut printing in Uganda, and the work itself, reflects his processing of the social, political and environmental changes that he has witnessed in Uganda over the years, as the country recovered from civil wars. His artistic practice activates memories of his childhood and then folds in his dreams about contemporary social realities to inspire the composition of prints that advocate for social and environmental justice (Figure 11). In recent years, he has been painting on barkcloth canvases and developing paper from barkcloth. His environmental work promotes the revitalisation of indigenous trees and barkcloth processing as central to community regeneration in Bukomansimbi.

Fig 11. Rich Harvest, woodcut print by Fred Mutebi

Fig 12. Indigenous tree nursery in Bukomansimbi

BOTFA is managed by farmer and community mobiliser Stephen Kamya, and comprises local farmers who use traditional agroforestry methods to manage a variety of food crops. Its regenerative farming practices include a nursery and planting programme for mutuba trees and other indigenous species to combat deforestation and climate change in the region (Figure 12). In addition, BOTFA trains the local youth in skills that may support their sustainable livelihoods, reinvigorate their communities, and prevent an exodus to urban areas where young people can end up in squalor, and delivers workshops for schoolchildren to foster environmental stewardship (Figure 13).

Interviews with BOTFA members, conducted by Kirsten Scott in 2019, mediated by Fred Mutebi, revealed that the mutuba tree naturally improves soil health and stability, and thus crop yield. The mutuba tree is vital to providing shade for food crops such as yams, coffee, and banana, as well as every part of the tree carrying medicinal properties – in addition to supplying barkcloth. Ninth generation barkcloth-processors shared that for hundreds of years their families had grown mutuba trees and they had always kept their land fertile, delivering nutrients to the soil and demanding little water. This is in stark contrast to the non-indigenous eucalyptus trees that have become ubiquitous in some areas of Uganda, draining the soil of nutrients and moisture across large areas and impoverishing nearby crops. The interviews underlined the importance of locally-specific agroforestry in providing vital ecosystem services: including enhancing soil health and fertility, regulating moisture, binding soil particles, preventing soil runoffs and erosion – all of which are crucial to regenerating depleted agricultural land for sustainable food production, in addition to mitigating climate change (Fahad et al 2022). Bioregional agroforestry is gaining popularity in the global North, but has always successfully been practices by many indigenous communities in the global North; this research confirmed its enduring value to the community of Bukomansimbi.

Fig 13. Agroforestry training by BOTFA.

Lesli Robertson (textile artist, consultant and researcher, with the Smithsonian Centre for Folklife and Cultural Heritage, and founder of Mekeka Designs) has worked closely with Fred Mutebi for amny years, and with BOTFA since its inception, and now employs her expertise as a weaver and natural dyer to offer custom design services that use barkcloth and other Ugandan plant fibres in novel ways for a range of contemporary items that include accessories, interior installations and products, and even architecture. Barkcloth strips are woven with other natural fibres in Uganda to be used in mats, cushion covers and other interior products, while commissions have come in from major technology firms and other organisations. A recent collaboration between Mekeka Designs, Yale Center for Ecosystems and Architecture (Yale CEA 2024), and textile designer Rowland Ricketts extended the possibilities for barkcloth in sound-absorbent woven barkcloth and cotton wall coverings. Lesli draws on craft thinking are well as entrepreneurial acumen to work intuitively with the materials, uncover new ways of using them and testing their commercial viability in the market. Lesli established a tree adoption programme with Fred Mutebi and BOTFA, that incentivises mutuba tree growing in Bukomansimbi: farmers receive welcome extra income and adopters are given the geolocation for each tree, the name of the specific type of mutuba, its age, and the name of its barkcloth harvester – which provides traceability in any products they purchase.

Fig 14. Mats incorporating woven strips of barkcloth. Mekeka Design, 2024

Fig 15. Barkcloth incorporated in wall coverings in a collaboration with Yale CEA and Rowland Ricketts.

Discussion and Contribution

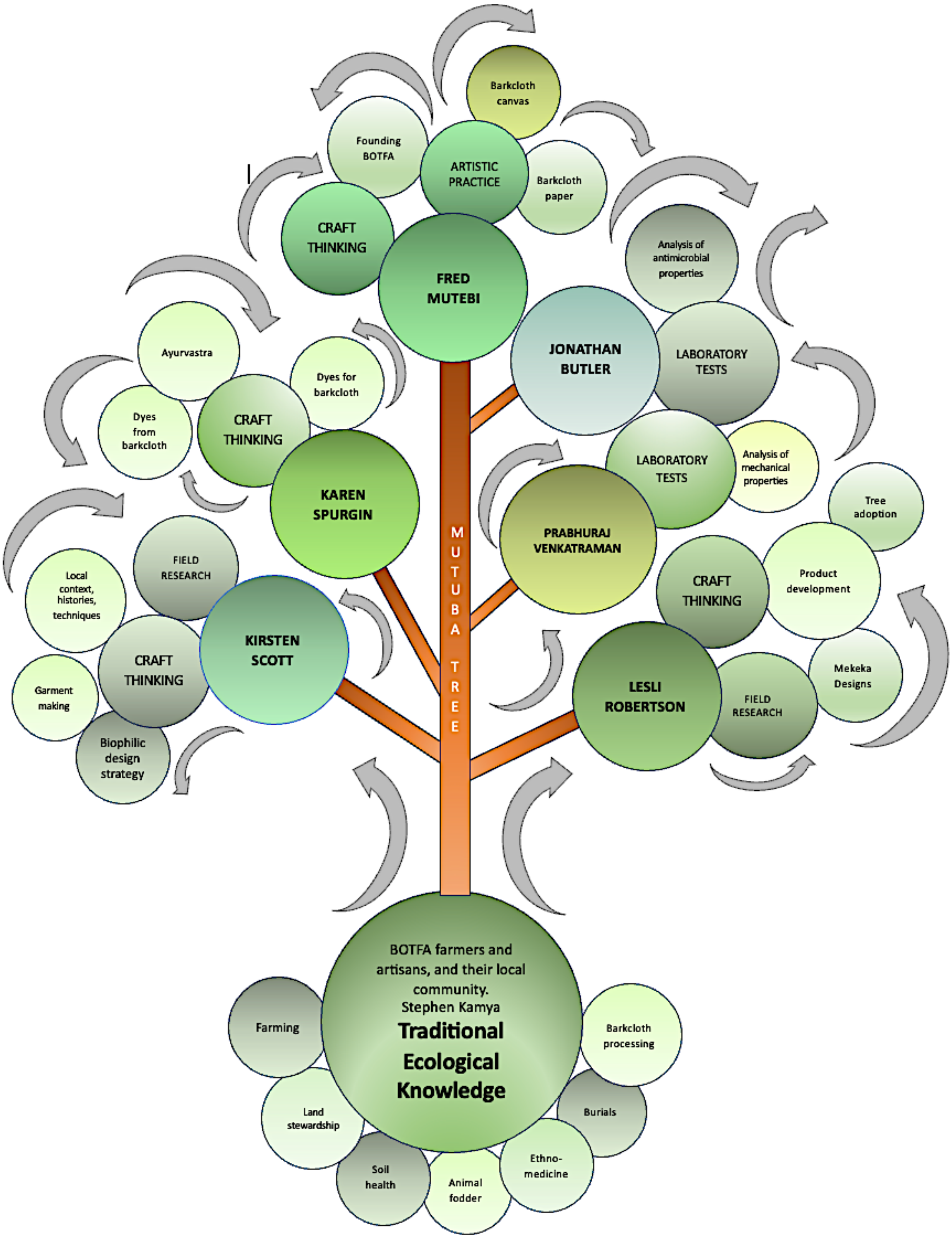

Fig 16. Barkcloth Research Network team members, methods, flows and outcomes

This research demonstrates the potential of craft to assist in resolving complex, wicked problems and advances the role of craft-thinking in brokering new relationships and possibilities between people, disciplines and trees (Figure 16). It demonstrates the role of craft practice in driving the formation of an agile, multi-disciplinary network with the potential to contribute unanticipated solutions to global challenges. Craft thinking has instigated and propelled this research, in listening to and responding to what the barkcloth has told the researchers – both practically and conceptually. It offers a fluid, agile and reflexive method of possibility-finding, testing, expanding and refining. The more intuitive, serendipitous, materials-led research of the designer-makers and artists in the team has been complimented by the very different, more structured lenses offered by the scientists, and by the TEK of local actors in Bukomansimbi, as each has folded in to the project (Figure 16). The research evolved organically to focus on the wellbeing of people, through biophilic design strategies and the prospective benefits of wearing barkcloth, or clothing dyed with barkcloth; and the potential of barkcloth in combatting methicillin-resistant wound infections. It advocates for the wellbeing of our planet by amplifying the role of local agroforestry systems in promoting soil health – in this case the mutuba tree in Bukomansimbi. This investigation of barkcloth advocates for the urgency of re-examining (not extracting!) TEK systems that embody centuries or millennia of experiential knowledge. There is no place for disciplinary or geographical boundaries, if we are to find solutions to the wicked problems that confront us.

The mutuba tree nourishes soil, provides shade for food crops, fodder for livestock, multiple and diverse medicinal benefits, is locally known to be mosquito repellent, sustainably provides barkcloth for clothing and accessories, interior products such as screens or drapes, and effective wound dressings, helps to combat climate change, and supports cultural resilience in Uganda. If just one tree can deliver so many benefits to people and planet, how much more might a whole forest provide?

Next steps

Further testing will take place to measure the effectiveness of different sub-species of ficus natalensis in treating wound infections, the active compounds identified, and their Luganda names matched to their Latin names where possible. Fabrics dyed with barkcloth will be tested for anti-microbial properties too. Clinical trials will be conducted to measure any benefits to the wellbeing of people from wearing barkcloth. Experiments will be made to find ways of retting, spinning, weaving and knitting barkcloth fibre, to discover more ways of using barkcloth in clothing.

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AlgaeCobogó

Living multicoloured curtain walls towards new materiality in architecture

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Sahima Hamlaoui (algologist)

Alice Araujo Marques de Sá (designer, artist)

Keywords: Microalgae, cobogós, natural light, colour perception, bioeconomy

Introduction

Designing with living organisms enables investigation and exploration into largely uncharted domains. At the intersection of biology and technology, design allows for bridging and reconnecting human-made objects with living matters. In Bioart, another creative area at this frontier, life processes are employed to represent science and to raise ecological awareness also pushing the barriers between the living realm and the technical context (Adenis, 2021; Giraud, 2012; 2024; Smith, 2024). Biodesign enables the use of living properties of organic matter for creating and improving functionality in objects while equally promoting new user interaction (Dongen, 2014; Klingler, no date).

Art, design, and architecture are interconnected disciplines, each characterized by specific yet overlapping approaches and focuses. While Art focuses on conceptual ideas, self-expression, emotion involving experimentation, abstract and technical skill, Design is a broad field with multiple sub-disciplines (e.g., fashion and industrial design) that encompasses several fundamental principles and resources for improving form, function, and user experience, also involving iterative processes, prototyping, and user-testing, including sustainable and social awareness (Bonsiepe, 2011; Cardoso, 2012; Papanek, 1985). Architecture is a multifaceted area, which includes additional layers of complexity, as it integrates creativity, project planning, construction, and other physical structures addressing the requirements of comfort, accessibility, and utility. Furthermore, it demands a deep understanding of materials, structural integrity, and environmental impact.

The notion of 'sustainability' as an opposite to the realm of 'aesthetics' is a common misconception. Natural matters have the potential to overcome and bridge the gap between these two supposedly opposite perceptions (Lee, 2011). There are several approaches within the nature-based design framework, such as bioinspiration, biomimicry, biophilic design, and living building materials (Chayaamor-Heil, Guéna and Hannachi-Belkadi, 2018; Sá and Viana, 2023). In fact, biodesign and biomimicry have been progressively used in architecture but there are still significant constraints on the transfer of biological knowledge and the integration of living organisms into design practices, which require specific models and methods, especially for creating analogies and adopting adequate abstraction processes, also including social and ethical acceptance (Chayaamor-Heil and Vitalis, 2020; Chayaamor-Heil et al., 2024).

The integration of living organisms in architecture and in construction industry remains largely limited to a biophilic design approach; where plants, green walls, and roofs or even tree structures (Baubotanik[1]) become part of architectural elements (Gong, Zoltán, and János, 2023; Ludwig, no date; Browning and Ryan, 2020). The use of microorganisms in architecture is indeed a relatively novel and emerging field, and has yet to achieve a widespread acceptance, due to multi-requirement and regulatory, safety, hygiene, functionality, and user-related constraints (Chayaamor-Heil et al., 2024). Nevertheless, several innovative concepts and experimental projects demonstrate the potential of integrating such living organisms into building design. Notable examples include self-healing concrete, biocement (using *Sporosarcina pasteurii*), bioluminescent passive lighting, and algae façades (Chayaamor-Heil et al., 2023). Among these, algae façade designs are considered the most advanced applicable

[1] *Baubotanik* is a building approach in which architectural structures are created by the combination and interaction of technical joints with natural plant growth. The term entails the practice of designing and building structures using living plants (Ludwig, no date).

prototypes, due to the progress of photobioreactor technologies that enable survival and reproduction of microalgae within architectural context (Pruvost, 2014; Pruvost et al., 2016).

Moreover, algae biomass is one of the most efficient energy sources, which can be converted into bioenergy through the absorption of atmospheric CO_2 via photosynthesis. Buildings are significant energy consumers, therefore, there are many explorations and progress on designing building façade systems that aim to utilise the biochemical process of photosynthesis to enhance energy efficiency. But, the integration of algae into architectural materiality presents several challenges. While some proposals for algae façade systems exist, deeper investigation and experimentation of varied geometries and different typologies are essential to better adapt to specific architectural scales, functions, and social and cultural contexts (Kim, 2022; UOOU Studio, 2024; XTU, 2024). It is important to emphasize that algae colonies can limit visibility, due to their lack of full transparency. So, algae façade panel systems prevent natural light from effectively entering the building because of the density of the algae liquid mass. 'Natural light' is indeed an essential element in architectural design, enhancing both aesthetics and functionality while fostering a healthier indoor environment. Thus, including visually permeable elements in the façade, such as the Brazilian *cobogós*, could be a strategy to overcome the lack of transparency in algae panels. *Cobogós* are solar control architectural elements for building openings, that were broadly used in Brazilian modernist architecture. These breeze blocks are one of the passive building façade design strategies in vernacular architecture, allowing the entrance of sunlight into building interiors to enhance visual and thermal comfort (Rodrigues, 2013; Delaqua, 2017). In the contemporary context of climate change and other environmental challenges, the creation of active or hybrid façades co-designed with living organisms is increasingly being proposed to compensate and complement the passive ones. These new biologically-hybrid systems address multi-functional needs, interacting with outdoor environments, while simultaneously providing interior thermal and visual comfort. As Lee (2011) noted, the concept of 'sustainability' is often considered to be contrasting with that of 'aesthetics'. In this context, the present work also explored experimentation with chromatic perception, by utilising different algae species with varying spectra.

Through the interdisciplinary collaboration between an architect, a designer-artist, and an algologist, the authors blended art, design, science, and creativity within this framework to propose a new type of façade – a living multicolored wall *AlgaeCobogó*. This façade proposal was co-created with five different species of microalgae, each having distinct spectra, ranging from *chlorophylls* (green) to *carotenoids* (red, orange, yellow), to *phycobiliproteins* (blue, red). These species were combined with Brazilian traditional *cobogós*, which have aesthetically various geometrical patterns. The authors analysed microalgae strains, their descriptions, and specific growth conditions to better understand the required parameters, establishing and refining the selection of algae species for façade design. The microalgae strains and culture methods studied were sourced from the culture collection of the French National Museum of Natural History of Paris[2] (Hamlaoui et al., 2022). Finally, by mixing microalgae pigments with the traditional latticework of *cobogós* it is possible to achieve both aesthetic and functional excellence, advancing living-architecture materiality that promotes a unique colour perception and sensory experiences of 'vitalism'.

[2] The National Museum of Natural History of Paris (MNHN), © Publications scientifiques du Muséum National d'Histoire Naturelle de Paris, Cryptogamie, Algologie, 2022

Cobogós: history and applications

Optimising sun protection and environmental comfort are essential aspects of architectural design that have developed over time. Reinterpreting and adapting elements of traditional and vernacular architecture can lead to the development of solutions that reduce and mitigate ecological impacts. From this perspective, it is worth highlighting an architectural element characteristic of Brazilian architecture, the *Cobogó* (Figure 1). The name of such an architectural element is an acronym composed of the first syllable of the last names of its three creators: Antônio de Góes, Amadeu Oliveira Coimbra, and Ernest August Boeckmann. *Cobogós* are a typical expression of Brazilian modernist architecture, commonly employed as a passive bioclimatic solution. They function as permeable walls that allow natural light and wind to pass through, acting as an element of thermal control, attenuating the incidence of direct solar radiation. Additionally, *cobogós* offer privacy to the inhabitants of a given space (Camacho et al., 2020; Santana et al., 2023).

Brazilian architecture exhibits a notable diversity, reflecting the country's varied climatic typologies and the countless influences of local and international cultures. However, one common denominator is the abundance of sunlight and high temperatures, thus requiring the appropriate design of windows and openings to provide thermal comfort, given the constant need for cooling and ventilation (Associação Brasileira de Normas Técnicas, 2005). These considerations were particularly embraced by architects of the modernist movement during a period characterised by the pursuit of national identity. This led to a high-quality architectural expression that was well adapted to the country's climatic conditions, often featuring *cobogós* as a façade element (Camacho et al., 2020; Silva and Góes, 2022). The historical origins of the *cobogó* are rooted in the influences of Arab architectural heritage, more specifically, in the *mashrabiyas* — wooden lattices that form complex geometric patterns used for solar control and that provide privacy to indoor spaces. Over time, Portuguese culture incorporated these elements and reinterpreted them in the form of *gelosias* and *rotulas*. Other references that possibly inspired *cobogós* include *claustras* of European churches. This set of elements and characteristics influenced the development of traditional Brazilian architecture. Later on, the modernists revived and redesigned this historical ensemble of elements, leading to the creation of the prefabricated hollow bricks now known as *cobogós*. They were patented prior to the widespread use of brise-soleils by Le Corbusier in 1933. Indeed, *cobogós* differ from brise-soleils as they are fixed modular features that not only provide thermal comfort and protection against rain and strong winds but also constitute the skin of the building (Andrade et al., 2021; Silva and Góes, 2022; Vettorazzi et al., 2024).

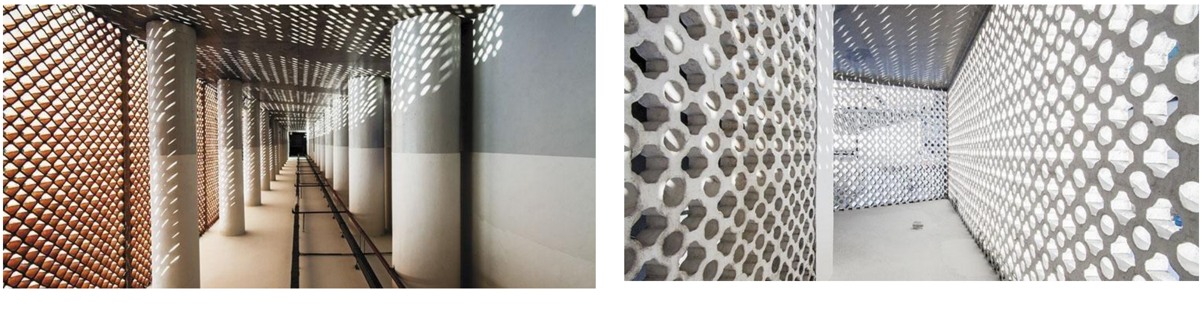

Fig 1. Rodrigues (2013) Interiors of buildings with cobogós. Natural light effects and shadow patterns create a visually engaging environment as sunlight passes through the breeze blocks during the day.

The diversified nature of projects with *cobogós* stems from its versatility, as it can be used both for façades and as partitions for internal environments, replacing conventional walls. Additional features include the low cost of *cobogós* (as they are prefabricated), their ease of application, and the environmental comfort they provide through thermal regulation, natural lighting, and ventilation, thereby reducing the need for costly artificial climate control systems. *Cobogós* are manufactured using many materials, including concrete, ceramic, glass, brick, natural fibres, plaster, and wood (A Bioclimática, 2024). A wide array of designs has emerged, providing aesthetically pleasing patterns that range from simple geometric shapes to complex, organic, and sculptural forms, often featuring variations in the openings. Thus, these distinctive characteristics make *cobogós* appealing to both specialists and the general public (Andrade et al., 2021; Piesco, 2020). Considering the aforementioned, *cobogós* can be classified based on the size of their openings (e.g., small, medium, large) and their geometry (e.g., simple extrusions with geometric motifs, simple extrusions with organic motifs, three-dimensional with simple projections, and three-dimensional with salient projections). The *cobogó* has a considerable aesthetic and ludic appeal since its intricate openings produce poetic shadow and light effects that create graphic compositions and patterns that are projected across indoor spaces over the day, changing according to the position of the incoming sun rays. As c*obogós* are objects closely associated with Brazilian cultural expressions, they have gone beyond architectural boundaries, giving rise to a variety of applications inspired by these elements in the design of furniture, decorative objects, and even a typographic dingbat-based style (Camacho, Sacht and Vettorazzi, 2017; Santana et al., 2023).

In summary, the *cobogó* is significant not only for its functionality, which is especially relevant in areas that require permanent ventilation, but also for its historical, cultural, and artistic relevance, as it is a symbol of Brazilian design and an interesting reference in contemporary architecture. However, this component has its limitations, since it is a fixed piece with a passive function in the building. Thus, rethinking this architectural component from the perspective of multifunctionality, increasing its responsiveness, and making it dynamic and or active are perspectives to be further investigated allowing for innovative uses of this traditional Brazilian element to be explored in new materiality contexts (Andrade; Beirão; Arruda and Cruz, 2021; Vettorazzi et al., 2024; Abdel, 2024).

Microalgae: properties and pigments

Microalgae are predominantly photosynthetic organisms that live in marine and freshwater environments, where they are the primary producers of oxygen and of valuable organic compounds (Franceschini et al., 2009, 2022). These microorganisms contain diverse pigments that play a crucial role in photosynthesis. Their coloration results from combinations pigments, which range from green to red, depending on the concentration of the dominant pigment of microalgae cells. Such pigments are classified according to their chemical composition and structure along with their spectral characteristics. Furthermore, microalgae produce a wide variety of natural pigments with diverse biological, chemical, and physical properties. Beyond their essential role in the life cycle and survival of these microorganisms, the pigments also represent significant potential for applications in biotechnology, medicine, cosmetics, food production, and the development of sustainable materials.

The main microalgae pigments and their properties are summarized below:

1. *Chlorophylls*: three types exist (Chlorophyll-a, Chlorophyll-b, and Chlorophyll-c). Presenting

the colour green, chlorophylls are the primary pigments in photosynthesis.

2. *Carotenoids*: there are five types (β-Carotene, Lutein, Astaxanthin, Fucoxanthin, and Zeaxanthin). Ranging from yellow to orange and red, they are strong antioxidants and UV-protective agents.

3. *Phycobiliproteins*: three types exist (Phycoerythrin, Phycocyanin, and Allophycocyanin). Are found in two opposite tones, red and blue. *Phycobiliproteins* are water-soluble and fluorescent and can be used as markers in scientific imaging.

4. *Xanthophylls*: there are three types (Zeaxanthin, Violaxanthin, and Canthaxanthin). All in different tonalities of yellow, they are antioxidants and UV-protective agents.

The coloration of microalgae is determined by environmental conditions and their adaptive abilities. Depending on the amount of light received and the conditions of its surroundings, microalgae develop pigments that are most appropriate to their situation. Under intense luminosity, chlorophyll production increases, resulting in a striking green colour. In other scenarios, where light is moderate, a combination of pigments produces a brown colour, while when there is low lighting, carotene pigments predominate causing microalgae to exhibit orange or red hues. The photosynthetic process in microalgae begins with the absorption of light energy by the chlorophyll pigments within the light-harvesting complexes (LHCs), which consist of proteins, chlorophyll, and carotenoid pigments.

The National Museum of Natural History of Paris (MNHN) is renowned for its extensive algae collection, which comprises about 80% of different freshwater species and 20% of marine species.[3] For the present study, the authors selected five different microalgae species from the MNHN collection displaying a diverse range of tones from green, brown, yellow, purple to red. This selection allowed for the study of microalgae pigments including their life conditions, functions, and properties and, also, their responses to external environmental stimuli. This context contributed to the development of conceptual propositions for a multicoloured algae façade, including the following species: 1) *Porphyridium purpureum*, 2) *Spirogyra varians*, 3) *Trentepohlia abietina*, 4) *Haematococcus pluvialis*, 5) *Centronella reicheltii* (Figure 2).

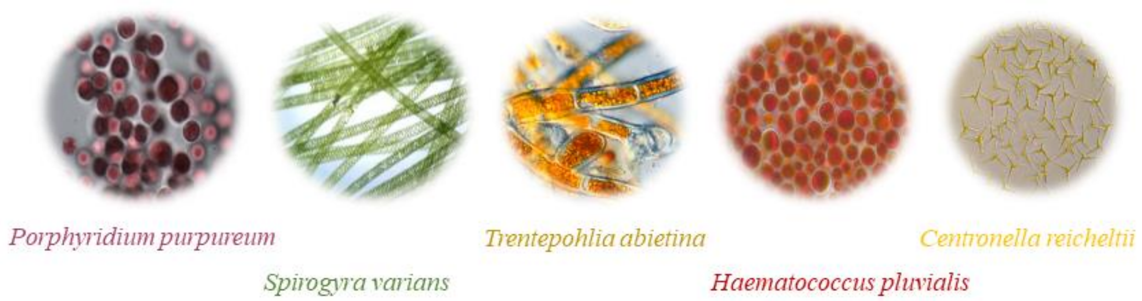

Fig 2. National Museum of Natural History of Paris (MNHN) (no date) The five species of microalgae were selected for their varied pigmentations.

Below, each species will be further detailed (Figure 2.1-2.5);

[3] The biggest marine algae collection in France is the Roscoff Culture Collection in Bretagne (Roscoff Culture Collection, 2024).

Fig 2.1(a). Natasha Heil (2024) *Porphyridium* cells actively growing on a new culture medium.

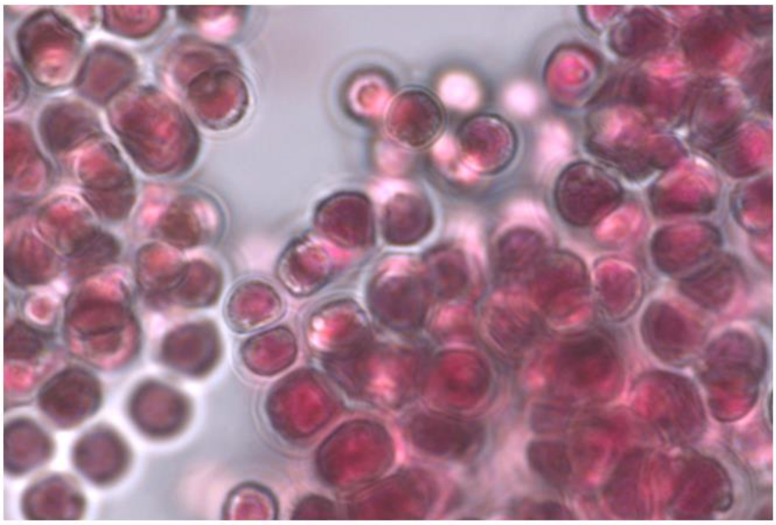

Fig 2.1 (b). Sahima Hamlaoui (2024) *Porphyridium purpureum* is currently commercially cultivated on a larger scale and is known for its production of sulphated exopolysaccharides and the accumulation of the valuable red *phycobiliprotein* complex and *phycoerythrin*.

Fig 2.1. Old cultures of Porphyridium purpureum, a red marine microalga, from the MNHN collection maintained in a controlled culture.

Fig. 2.2 (a). Natasha Heil (2024) Cultures of *Spirogyra varians* known as 'water-silk' and 'mermaid's tresses'. The pale green colour corresponds to old algal culture, the bright green was cultured in a recent and new medium, allowing for the algae cells to actively grow and thrive, resulting in a difference of coloration

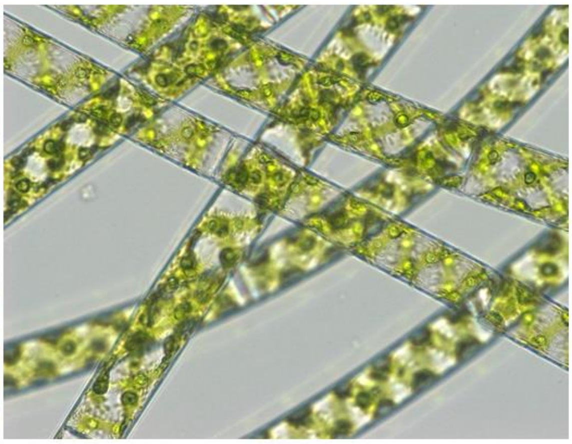

Fig. 2.2 (b). Sahima Hamlaoui (2024) Cultures of *Spirogyra varians* known as 'water-silk' and 'mermaid's tresses' . A filamentous green alga, from the MNHN collection kept in a culture room under controlled light and temperature.

Fig 2.2. The pale green colour corresponds to old algal culture, the bright green was cultured in a recent and new medium, allowing for the algae cells to actively grow and thrive, resulting in a difference of coloration.

Fig 2.3 (a). Natasha Heil (2024) *Trentepohlia abietina*

Fig 2.3 (b). Sahima Hamlaoui (no date) *Trentepohlia abietina*

Fig 2.3 (c). Fraxinus excelsior - English Wood (no date) *Trentepohlia abietina* on Ash tree

Fig. 2.3. Cultures of *Trentepohlia abietina*, a filamentous green terrestrial alga whose yellow-orange colour is due to carotenoid pigments that mask the green chlorophyll colour (a, b). Although algae are usually mainly known in marine and freshwater habitats, they also occur in a wide variety of terrestrial environment, as *Trentepohlia abietina* on Ash tree (c).

Note that *Trentepohlia* species are more adapted to non-shaded habitats. Recent studies on *Trentepohlia* have demonstrated its potential as a natural source of antioxidants (Kharkongor and Ramanujam, 2017). These species are found on many different substrates (rocks, tree bark, leaves, twigs, fruit, soil, woodwork, carved stone, concrete walls and pillars, metals, and plastics), where they can form large orange, red or yellow patches in sites with high humidity. *Trentepohlia* is often lichenized.

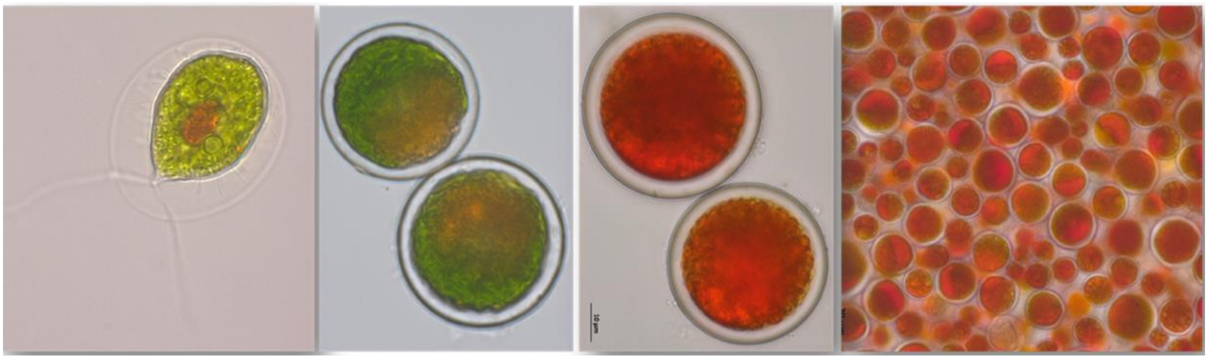

Fig. 2.4 (a). Sahima Hamlaoui (2024)

Fig. 2.4 (b). Sahima Hamlaoui (2024)

Fig. 2.4 (c). Sahima Hamlaoui (2024)

Fig. 2.4 (d). Sahima Hamlaoui (2024)

Fig. 2.4. The green freshwater alga *Haematococcus pluvialis* can exhibit different colorations. In favourable conditions, the cells are green and mobile with two flagella (a) during periods of stress (e.g., strong sunlight, drought, nitrogen or phosphorus deficiency); the cells start by losing their flagella and group together (b); then, the cell wall thickens and begins to accumulate a red pigment called *astaxanthin* around the nucleus (c, d); finally, encystment enables the microalgae to resist and survive until favourable conditions return. Algae Collections at The National Museum of Natural History of Paris (MNHN).

Haematococcus pluvialis is already commercially used for the production of *astaxanthin* as a source of antioxidants, for use as additives in human food and animal feed applications, in cosmetics, and as dietary supplements (Marino et al., 2020).

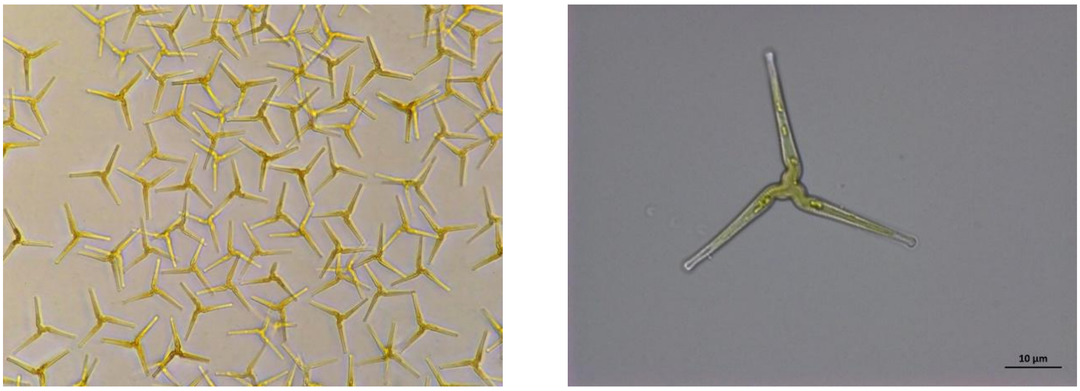

Fig 2.5. Sahima Hamlaoui (2024) The yellow, golden-brown freshwater algae Centronella reicheltii produces fucoxanthin and carotenoids that serve photoprotective and antioxidant functions. Algae Collections at The National Museum of Natural History of Paris (MNHN).

The role of colour perception, sensory experience, and psychology in architecture—particularly in façades, interiors, and exteriors—is profound. Colour influences human emotions, behaviour, and spatial perception, shaping how individuals experience built environments. It can create different moods and enhance architectural functionality, while also reflecting cultural associations and contextual sensitivity. Applying 'living colour' through the use of microalgae represents an innovative approach to developing natural, sustainable, and dynamic coloration in design and architecture. It is relevant to highlight that microalgae, as microscopic, photosynthetic organisms, are capable of producing vivid pigments. Thus, their integration into living systems offers a unique connection between science, art, and sustainability.

Methodology

Within the interdisciplinary art-design-science context, the authors developed a hybrid research framework bridging the disciplines of microbiology, art, design and architecture. This approach sought to generate new knowledge through scientific research, focusing on the possibilities to evoke emotion while mixing the domains of art and sciences, and using design and architecture techniques and processes as the main means for implementation. The adopted hybrid methodology incorporated microalgae as living elements within architectural façade systems, combining creative, functional, and scientific perspectives. The initial exploration was centred on the aesthetic potential of microalgae as a dynamic, living medium, focusing on its colour variations and the responsive designs that would interact with light, temperature, and other environmental aspects.

The authors used the Curiosity Microscope kit to observe and capture microscopic images of selected microalgae. The microscope is a tool developed by the Tara Ocean Foundation[4] (2024) in collaboration with the Plankton Planet[5] (2024) consortium. The strengths of the

[4] The foundation is dedicated to scientific expeditions to study marine biodiversity and to anticipate and monitor the effects of climate change and pollution (Tara Ocean Foundation, 2024) For more information access: https://fondationtaraocean.org/

[5] The initiative aims to expand the horizons of researchers' curiosity and creativity co-developing new universal scientific instrumentation for monitoring marine microbiome diversity (Plankton Planet, 2024). For more information access: https://planktonplanet.org/

Curiosity microscope lie in its high definition, its capability to capture both photos and videos with a simple connection, and its user-friendly design (Figure 3a). The authors took sampling microalgae from *Lac de Créteil* as a site selection to observe their living conditions, functions, properties in relation to their different stages of vital pigments (Figure 3b).

Fig 3 (a). Sahima Hamlaoui (2024) Curiosity microscopic kit provided by Plankton Planet

Fig 3 (b). Natasha Heil (2024) Sampling different species of microalgae from *Lac de Créteil* for microscopic analysis

After observing and analysing the five selected microalgae, the authors gathered comprehensive data on the life conditions of each species, in relation to their environmental requirements. It is pertinent to remember that microalgae pigments are specialized molecules that absorb light for photosynthesis and provide coloration. The pigments present in microalgae influence their appearance, determining the wavelengths of light they can efficiently use. Different tones of such pigments are influenced by both biological and environmental aspects. In the design exploration phase, all factors related to the selected microalgae were considered, combining them with the modularity and the scalability of a *cobogó* functional system, to integrate microalgae into façades. During the transfer phase, biomimetics was adopted as a scientific approach to understand the biological and ecological properties of microalgae focusing on their potential for energy generation, air purification, and thermal regulation, with a particular focus on optimizing algae growth and advancing photobioreactor technologies. The authors used techniques of algae cultivation in laboratory experiments at the MNHN, also conducting an environmental performance analysis.

Photobioreactor systems were used for the digital prototype. Indeed, existing algae-based façades are only available through photobioreactors, mostly, in flat panel configurations (XTU, 2024). However, recent designs illustrate more advanced algae façades that can be configured in interlocking arrangements allowing natural light into spaces, but such examples remain at the initial prototyping and testing stages (Kim, 2022).

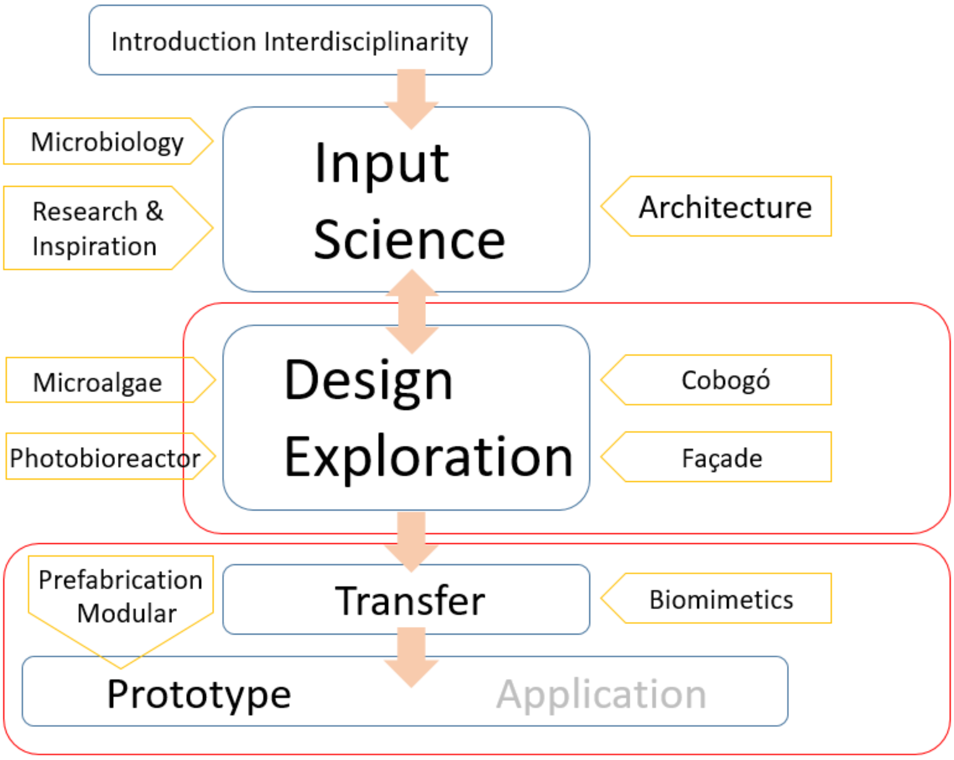

Fig 4. Natasha Heil (2024) Interdisciplinary design methodology implemented for creating the *AlgaeCobogó*.

Results

Upon completing the observation and analysis, design specifications were identified and summarized, integrating scientific, artistic, and design approaches for the development of a new concept of façade, the *AlgaeCobogó* (Figure 5).

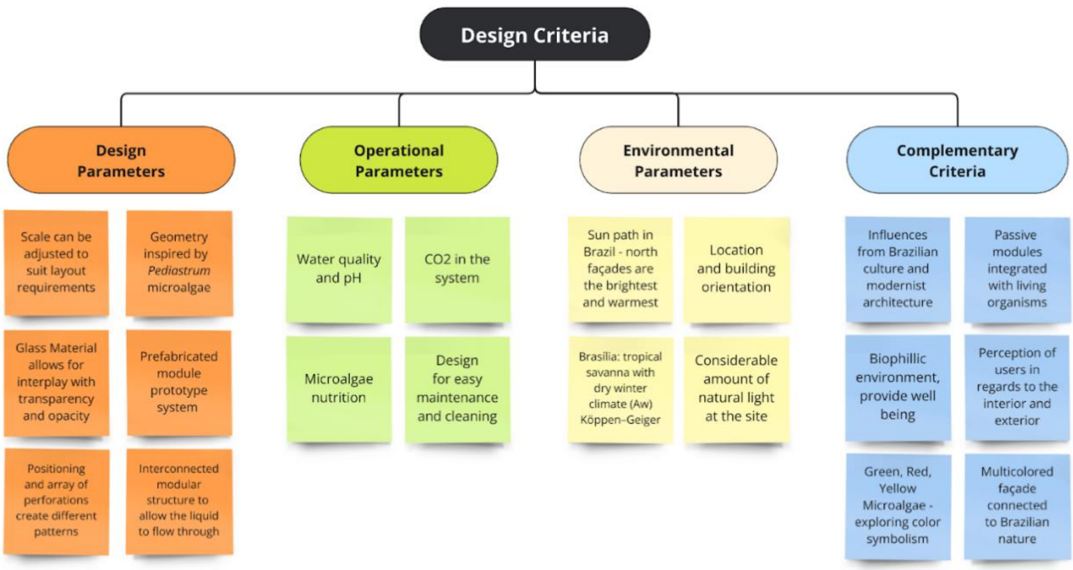

Fig 5. Alice Araujo Marques de Sá (2024) The adopted criteria included specifications of design, operational, environmental, and complementary parameters for the design and implementation of the *AlgaeCobogó*.

An example is provided in Figure 6, below, of a module composed of transparent or translucent materials (that are to be further specified) that would be used to culture microalgae inside. Different species with varied pigments and properties were chosen for each design, assessing which would be better suited to the application according to their functions, the sunlight exposure, and their required specific environmental conditions. This selection was also oriented by the indented architectural usage, and specific contexts and implementation sites (e.g., antioxidant, UV-protective, green energy).

The module features areas of varying opacity for containing and cultivating microalgae that would allow for collecting sunlight for photosynthesis and, also, for energy generation within the building. The perforated areas of the *cobogó* would promote natural light and ventilation. Each module was designed to be interconnected and disassembled, containing in its core the algae culture liquid. Thus, a system of connected modules with internal pipelines was created, allowing the microalgae liquid to circulate through the structure.

Fig 6 (a). Alice Araujo Marques de Sá (2024) Digital prototype of the *AlgaeCobogó*. Modules with different microalgae pigments

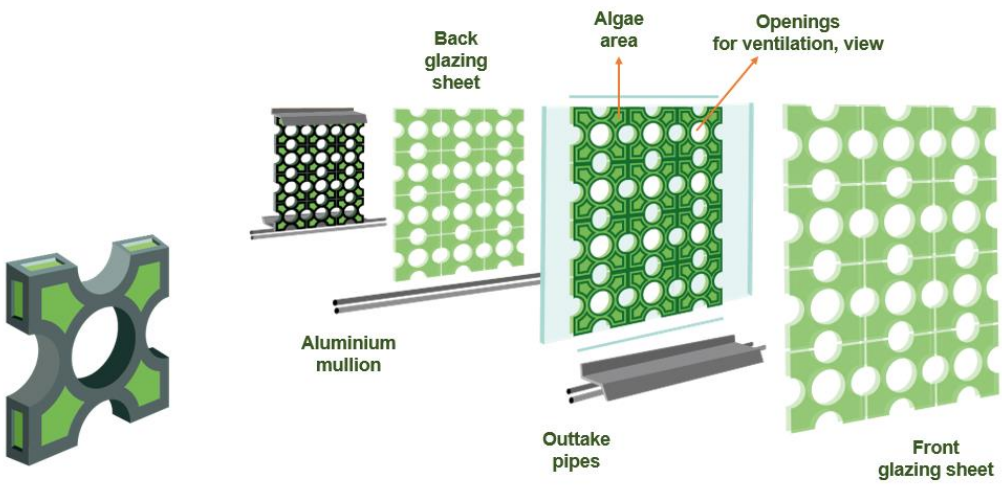

Fig 6 (b). Alice Araujo Marques de Sá (2024) Digital prototype of the *AlgaeCobogó*. A prototype at the façade scale for prefabrication that would be installed in a building located in Brasília, Brazil

The combination of an algae façade with a *cobogó* pattern demonstrates an original aesthetic composition, where new geometry and functionality meet, promoting performance excellence. The algae component of the façade absorbs natural light, converting it into energy used within the building. Some algae species can also effectively absorb CO_2 and other pollutants, while the opacity of the algae density protects from direct sunlight, mitigating extreme heat conditions. The small perforations with different geometrical patterns allow natural light to penetrate the building, also improving natural ventilation. The geometrical patterns further contribute to a new façade aesthetic, creating an original light-shadow pattern effects inside the space, that varies along the day, according to the sun's position.

Nevertheless, several challenges and paths for innovation require further investigation to implement a physical prototype of the present project:

1. Maintenance: microalgae systems require specific conditions such as adequate light, nutrients, and temperature control to thrive. Regular upkeep is essential to ensure consistent colour and performance for the system and the façade as a whole.

2. Durability: while living systems are visually striking, their longevity in architectural applications depends on robust containment and environmental compatibility.

3. Scaling Up: Transitioning from experimental to large-scale applications requires investment in technology and collaboration between scientists, designers, and architects.

Discussion

Although algae façade propositions exist, most are still at a speculative conceptual level (Hanafi, 2021). However, such concepts can expand the horizon of envisioned possibilities in the near future. The design concepts presented in this paper constitute significant contributions by demonstrating how to combine sustainability with aesthetics and how new forms and shapes can improve functionality and overall architectural considerations. The varied geometries and pigments available from different microalgae species provide opportunities to better integrate living matter into various architectural typologies and contexts. In the case of the present work, these biological elements were combined with the traditional *cobogó* pattern, reflecting the cultural context of Brasília, where the algae façade would be situated.

Designing with living organisms requires multiple paths of iterative experimentation and testing. Living organisms are inherently unpredictable and dynamic, thus, maintaining their viability demands specific and optimal conditions, much like the human necessity for comfort and for fulfilling basic needs. The integration of living elements in art and design has progressed further in the last few years comparatively to the architecture and construction fields. Indeed, to appropriately co-design with organisms within the architectural realm, it is important to fully embrace the vision of the "new ecological paradigm", and to address several crucial elements. These include developing advanced technologies, establishing innovative design processes, adopting digital and biofabrication techniques, creating new building and design standards specific to living matter, and working towards a shift in societal acceptance of such materials. Another key area for improvement is the development of a solid 'business model' to suit non-standard microalgae façades in the architecture and building industries. A supply chain must be established for the production and commercialisation of algae-based products. While cultivating algae is feasible, the business model success depends on the recovery and sale of microalgae. If more seaweed products are created, they can be more widely accepted in society, thus being less anecdotal or only 'novelty products'. Furthermore, educating the general public on the importance of co-living with other organisms, understanding their life conditions and ecosystems, and embracing the concept of buildings as vital components of the environment is essential.

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Shifting Horizons: Exploring the intersection of landscape & human experience in the evolving realm of sustainable glassmaking

Dr Giorgio Salani

Keywords: Sustainability, pottery, studio ceramics, craft, practice theory

Introduction

A growing emphasis on sustainability over the past few decades has transformed the manufacturing sector, including the ceramic industry. Recycling of sludge waste in European factories producing tiles and sanitaryware are optimised to high standards (see e.g. Boschi et al., 2020), diverting large quantities of waste previously destined to landfill. Factories can operate on renewable energy and the efficiency of industrial kilns has reached very high standards (Silvestri et al., 2019). By comparison, craft ceramic studios are lagging in environmental standards, lacking the efficiencies and technological investments associated with larger-scale factories. Craft is often associated with a respect for nature and appreciation of raw materials but making handmade pottery – like most manufacturing – also damages the environment.

Clay can be dug and pots can be shaped by hand or with simple tools. Once dried in the sun, they can be decorated with other coloured clays, minerals and oxides crushed from local rocks. But then we would hit the wall: it is hard to fire ceramics without polluting or relying at least in part on fossil fuels. In fact, contemporary craft ceramic production is surely more impactful than this ideal scenario. Practitioners working individually or in small teams in post-industrial countries such as the UK (i.e. studio potters) follow an established production process that starts with purchasing materials, tools and machinery from suppliers who refine and package mined clays and rocks. Pots are formed by handbuilding, slipcasting or throwing on the potter's wheel, left to harden, trimmed (or 'turned' in the UK) and fired a first time, typically in electric kilns (bisque firing). Glaze materials are then mixed in water and applied to the 'bisque' pots, cleaned and fired again in electric, gas or woodfired kilns. Negative environmental impacts are associated with every stage in this process, from processing the raw materials at the source to working in the studio, firing the kilns and even heating, cooling and lighting the workshop space (Salani, 2024a; Železný et al., 2023; Lo Giudice et al., 2017).

The sustainability of craft ceramics is a more complex issue than it may initially appear. Potters may care for the environment and reject the wasteful consumerism of contemporary society for a more considered, thrifty use of resources. Rooted in the values of the Arts & Crafts and in the writings of Bernard Leach (1940/1978), the appreciation of handmade ceramics often contrasts with the throwaway culture that characterises much industrial output. But pottery making remains an energy intensive process that transforms virgin materials into products that once damaged will be hard to reuse or recycle. And yet, many materials, tools, machinery and methods used in the craft have seen limited innovation in terms of sustainability in the last few decades.

Life Cycle Analysis (LCA) is an established methodology for assessing the environmental impacts of manufacturing processes. LCA studies show wide-ranging emissions for ceramic production, from 1.2 kg CO_2 per kilo of industrial sanitaryware (Silvestri et al., 2019) and even lower for bricks (Almeida, 2010) to over 5 kg for handmade tableware (Makliuk, 2023). Assessments are greatly sensitive to exact methodologies and assumptions, and the emissions can vary based on each workshop's materials, processes, machinery and energy mix. Despite the significant attention given to industrial production, there are few scientific studies on handmade pottery processes, and discussions in specialist magazines and other grey literature lack scientific validity. (Salani, 2024b). Practitioners welcome useful tips for saving resources and improving the efficiency of making processes (NCECA, 2022; Harrison, 2013), from straightforward systems to reclaim clay and glaze materials from sinks (Schimik, 2010) to complex experiments with atmospheric firings (see Salani, 2024b for a review of sustainable technologies). But quantitative assessments are rare and the environmental benefits of many solutions from a life cycle perspective remain untested.

Overall, this suggests a view of environmental stewardship that relies on the individual choices of makers who are conscious of the negative impacts their work may produce. This 'behaviour theory' view contrasts with 'practice theory' approaches which instead would target pottery making practices as the primary area of intervention (Shove et al, 2012).

This paper is informed by a systematic review of literature published in English on the topic of sustainability in craft ceramics since 2000 (Salani, 2024b), practice review and ethnographic research conducted at the Leach Pottery's production studio, in Cornwall, over the last 10 years. The analysis is centred on the UK context, but its findings apply to post-industrial societies more broadly. I offer reflections on key challenges in achieving sustainability in craft ceramics manufacturing. Inspired by practice theory, I analyse three recent case studies of best practices, suggesting recommendations for future research and initiatives to develop and evaluate eco-friendly solutions.

Challenges

Craft ceramics face some serious challenges in developing and implementing sustainability. The following paragraphs highlight a knowledge gap that hinders a clear definition of the issues involved - due to both lack of reliable data and sustainability education. Also, we suggest that by over-relying on the resourcefulness of their studios, makers end up neglecting more effective action.

Scarcity of scientific studies

In the UK and many other countries, craft ceramics as a sector lacks the legal or commercial requirement to conduct systematic LCA analysis and other environmental assessments. The scientific study of the sustainability of handmade processes has received relatively scarce attention despite a notable, general and growing interest in pottery, craft and sustainable manufacturing.

A recent peer-reviewed study compared 5 methods of tableware production, including ancient technology, wheel throwing and factory processes (Železný et al., 2023). The ancient method was found to be the most polluting "due to the particles released into the air during biomass combustion". Studio pottery was more sustainable, emitting 3.1 kg CO_2 eq. per kilo of pottery, compared to the 3.6 kg of factory production. A previous study showed that decorative hand-painted plates in Sicily were responsible for 1.26 kg CO_2 eq. (Lo Giudice et al. 2017), in line with the figures published for small tableware factories in Thailand (Chuenwong et al. 2017). For studio production, a recent study recorded 5.4 kg CO_2 eq. (Makliuk, 2024), while my analysis of the Leach Pottery (conducted with Prof. Xiaoyu Yan from Exeter University) measured 3.2 kg (Salani, 2024a).

Generally, tableware tends to have higher environmental impacts compared to other typologies, and craft processes are often associated with greater emissions than their industrial counterparts. Variation in making practices, technologies, ceramic typologies and energy mixes in the countries of operation may explain why these analyses of small-scale production present coherent but different results. The scientific literature currently available provides much needed insights on this issue but has not caught up with the resolution required by craft practitioners to make informed choices.

Poor understanding of sustainability

A widely accepted definition of environmental sustainability is "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987). Achieving sustainability in craft ceramics requires specialized knowledge of environmental science, energy systems, and life cycle analysis—areas often outside the expertise of potters. Even if more scientific research were available on the topic, practitioners would not be able to reduce their impacts on the environment without a better grasp of its complexity, as low literacy can lead to ineffective or counterproductive actions.

An example from my ethnographic research illustrates this point. Many environmentally conscious potters are eliminating plastic from their packaging, particularly in the UK. Using a combination of cardboard boxes, honeycomb paper and starch-based peanuts is increasingly popular (Fig. 1). The peanuts are compostable and replace those made of polystyrene, often disposed in landfills after a single use. Makers (and likely their customers) often take the benefits of these materials for granted. A recent US study (Forfora et al., 2024) asks whether starch-based materials are more eco-friendly than fossil-based ones, noting that it depends on the impacts considered. While starch-based foams emit less carbon during production, growing the crops has greater negative effects on land and water. Carbon emissions range from 1.3-3.2 kg CO_2 eq. for starches and 0.7-6.7 kg for plastics, meaning plastics can be either less or more carbon intensive. Reusing either material would have no extra impacts, with polystyrene being more durable. Without clear environmental labelling, it is hard for potters to make informed choices. Our consumerist habits make us look for new "eco-friendly" materials to buy, whilst we could 'reduce, reuse, and recycle' the newspaper, cardboard boxes, and even plastic peanuts we already have. In the UK, a third of cardboard is not recycled and producing 1 kg of recycled cardboard emits 1-1.5 kg CO_2 eq. (Greenmatch, 2025), while reusing an old box does not. In our LCA study of studio pottery, packaging accounted for 18.6% of total emissions (Salani, 2024a). Makers with higher sustainability literacy would be better equipped to question the automatic adoption of seemingly green solutions, whilst better informed customers would be less impressed by the replacement of one polluting material with another.

Figure 1 - A machine used to wrap pottery in paper (left, credits: author) and starch peanuts used in packaging (right, credits: Wikipedia Commons)

Privileging a studio mindset

The transformation of clay and glaze materials into ceramics occurs within the confines of the ceramic studio. Authors and readers are eager to share tips and techniques aimed at increasing the efficiency of their processes, potentially saving them time, effort, energy, materials and money. Some actions can be implemented without interfering with the creative process and are widely shared: reclaiming used clay to make new pots (Levenstein, 2015), using a bucket system to collect glaze waste and avoid clogging the sink (Schimik, 2010), or maximising the number of pieces that can fit in the kiln in each firing. Other solutions require more advanced material testing and may alter the physical qualities of the ceramic pieces produced: lowering firing temperatures - typically from cone 10 to cone 6 (Field, 2007) or substituting virgin materials with recycled ones (Howard, 2020) requires a more proficient understanding of the pottery process and iterative attempts to reach the qualities desired.

Comfortable in their familiar spaces and empowered by the creative possibilities of studio operations, makers may fail to recognize the interconnectedness of their craft with multiple industries and stakeholders that lie outside of studio boundaries: mines and quarries that extract and refine raw materials, suppliers who gather resources from multiple industries, kiln manufacturers that dictate the efficiency of firings, tool and machine manufacturers, energy suppliers, storage and delivery companies and many others. LCA studies show that most of the carbon footprint associated with pottery making relates to the procurement of raw materials and energy consumption during firings (Salani, 2024a; Železný et al., 2023). However, the studio mindset privileges a focus on efficiency measures and savings that can be obtained with minimum disruptions to established procedures. This leads to a discourse on sustainable ceramics dominated by studio tips (e.g. NCECA, 2025; Levenstein, 2015). More radical approaches that can reconfigure ceramic practice beyond studio operations (such as the best practice discussed in the next section) are rare and, arguably, originate from makers with less established studio mindsets.

Slow technological and material innovation

Limited demand for, and investment in, sustainable solutions may be a key factor in their relatively slow advancement. For example, the practice of utilising waste vegetable oil (WVO) in atmospheric firings is a proven technology that is not yet available on the market. WVO has the double advantage of replacing non-renewable fuels (e.g. gas) while diverting waste from landfills. The technology has been demonstrated in various occasions but remains highly experimental to the point that practitioners exchange notes on making their own burners (NCECA, 2017). Similarly, reduction electric kilns are relatively common in Japan but not in the UK or the US. They could help achieve similar qualities to gas or wood firing but with a much-reduced impact on the environment (especially if powered by green electricity).

Scarce innovation in the production and consumption of ceramic materials has also hindered sustainability. For example, labelling the toxicity of glaze materials on the packaging is common practice today, but indicating geographical origins and carbon footprint remains unheard of.

Making handmade pottery requires that materials come to contact with human hands at various stages, and this limits the range of unorthodox materials that can be safely handled in studios. Projects incorporating waste from potentially polluted sources employ slipcasting in small factory settings rather than throwing or handbuilding in studios (e.g. Earth Tatva, 2025).

Finally, the comparatively high environmental impact of ceramic firings underscores the importance of improving kiln efficiency. However, it is still common among established UK workshops to build their own gas or wood-fired kilns, which, despite being less efficient and poorly insulated compared to the more advanced commercial models, are more affordable and easier to repair on-site without incurring additional technician fees.

In summary, the factors hindering sustainability innovation in craft ceramics are technical, financial, market-driven and cultural.

Steps forward

The best practice in this area of manufacturing can be exemplified by the three case studies described below. While some aspects of these projects are in line with other makers' initiatives to improve studio practices, what makes them remarkable is how they overshadow the focus on efficiency and 'green tips' for studio work by creating new regenerative platforms and innovative material practices around clay and ceramics.

Grandby Workshop

Circular exchange of materials between local businesses and industry can transform ceramic supply. Some of the most interesting recent projects are doing exactly that: challenging the traditional foundations of studio ceramic practice. The Granby Workshop is a collective of makers related to Assemble, the group of artists who received much attention since being awarded the Turner prize in 2015. The group is well-known for their architectural ceramics made by merging the creative freedom of studio pottery with industrial manufacturing processes such as press-casting. Involved in the redevelopment of a row of Victorian derelict houses in Liverpool (the Granby Four Streets project), they produced various architectural elements using clay, industrial ceramics and demolition material salvaged from the buildings. The project has been praised for embodying the revitalisation of the area through an original aesthetic inspired by ruins and demolition (Charles, 2018).

The project breaks the habitual processes of studio ceramics. Instead of simply producing attractive pieces for the newly renovated buildings, the skills of studio makers are put to the use of the construction team. Some of the output is straightforwardly studio pieces, such as terracotta lampshades and doorknobs wrapped in tin foil and 'pit fired' in a barbecue (Fig. 2, left). Others are custom products that merge the creative freedom of craft decoration (colourful decals) to the reliable standards of (cheap) blank industrial tiles. Another successful solution is the so-called Granby Rock, a series of terrazzo products that incorporate the rubble of demolition to create colourful attractive surfaces resembling conglomerate rock. Staying within the confines of studio practice, ceramic rubble could be handpicked and ground to fine particles to be used as 'grog' in clay bodies. However, this would require considerable resources and leave much concrete waste unutilised. A strong concrete material was instead produced from blocks of concrete, stones and ceramic waste. This was moulded, cut and formed into fireplaces, tables, kitchen tops and furniture. The project convincingly combined studio ceramic knowledge with experimentation with industrial machinery and construction waste, all delivered in a highly polished design aesthetic.

For another project, the collective produced tableware (Granbyware) entirely from industrial and post-consumer clay waste. Glaze was similarly created from the amalgamation of clay waste with other recycled materials such as crushed rocks, glass and bricks (Fig. 2, right). The team pointed out that some of the most iconic ceramic products of the past, such as bone china and the London stock bricks, were themselves the results of experimentation with reusing recycled materials from other industries -i.e. burnt cow bones and chimney ash, respectively (Dezeen, 2019).

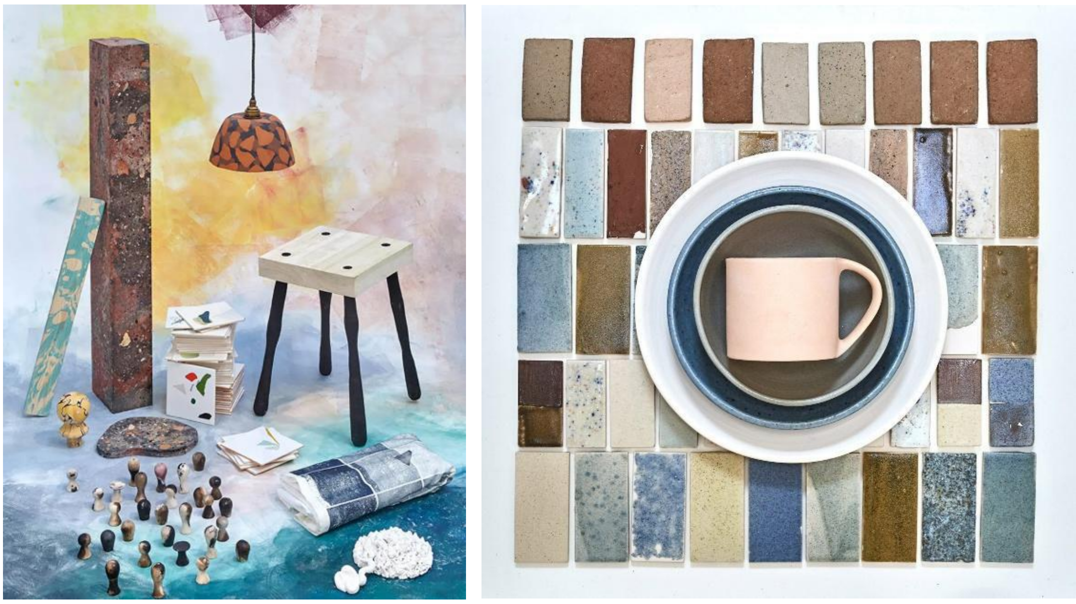

Figure 2 - Products from the first Granby Workshop catalogue, 2015 (left) and material tests for making the Granbyware (right), (credits: granbyworkshop.co.uk)

Circular Ceramics

After years of experimentation that started with her degree work at Central Saint Martins, Sara Howard's Circular Ceramics project (Fig. 3) is a "a fifteen-piece tableware collection, available in two colourways and made from 70% -100% secondary resources destined for landfill" (Howard, 2025). Following an approach shaped by regenerative design and the circular economy, Howard applied her ceramic knowledge to alleviating the negative impacts of mining and industrial waste as well as scarcity of resources (Howard, 2020). The tableware is produced through a process described as 'industrial symbiosis' with local businesses at the Kevala ceramic factory in Bali, bypassing conventional procurement of clay and glaze materials, diverting waste from landfills and reducing the environmental impacts of multiple businesses at once.

The formulation of the project originates in studio approaches and manual experiments, and the tableware range is hand-thrown by artisans in the factory. However, the procurement of the raw materials required the establishment of a local waste network and the industrial crushing and sieving equipment of the ceramic factory to obtain usable resources. The collection is made using glass waste collected from rivers in Bali, slurries from local marble and granite manufacturers and internal factory waste, "resulting in over 16 tonnes of waste diverted from landfill annually" (Howard, 2025). The clay body is entirely made of reclaim from factory wastewater, while one glaze is 100% residue from other lines' glazing process. As conceptual and innovative as the Granbyware described above, the Circular Ceramics collection is also a commercial product currently available for purchase.

Figure 3 - The Circular Ceramics collection by Sara Howard (credits: sarahowardstudio.com)

Golden Earth Studio

The team is a Wimbledon-based collective of local artists, ceramicists, students and communities pursuing circularity by replacing the common use of commercial bodies and quarried materials with clay from excavation waste that is otherwise destined to landfill. Through initiatives advertised on social media, they make clay from construction excavation in the London area available to makers interested in the sustainable sourcing of raw materials for creative expression. The clay is not sold but offered free of charge through their website. Working in partnership with construction and demolition companies, they aim to "make by-products from construction sites accessible" (Golden Earth Studio, 2025).

The alternative sourcing of raw materials for studio production follows a popular trend in 'wild clay' (Levy et al., 2022) and can be effective in promoting education in the chemistry and geology of ceramic materials. The studio claims to have diverted 1.6 tonnes of the 29 million tonnes of excavation material go to landfill every year. The initiative disrupts the common purchase of virgin materials from pottery suppliers and can potentially divert large quantities of construction waste from landfills. While the scale of the operations is small and localised, the project demonstrates that such an approach is possible and can pave the way for larger-scale implementations. In fact, the studio has recently announced a similar initiative in San Diego, California (Golden Earth Studio, 2025).

Figure 4 - Making ceramics from salvaged materials (credits: goldenearthstudio.co.uk)

Recommendations

The interpretation of the case studies through 'practice theory' (Shove et al., 2012) can help shed light on the issues discussed in this paper, addressing the challenges described above and informing some key recommendations for practical initiatives and future research.

Social practice theory as proposed by Elizabeth Shove at Lancaster University builds on Gidden's structuration theory and Bourdieu's concepts of habitus and field, which are influential in craft studies. Structuration theory highlights how the material practices that shape the work of potters and ceramic artists are socially constructed and perpetuated through performances. Shove points out the need to interfere with the "recurrent enactments" of contemporary studio ceramics and create "novel combinations of competence, materials and meanings" (Shove et al., 2012). This shifts the focus from individual potters making better choices to fundamentally reshaping the unsustainable systems of practice that hide behind current studio ceramics.

What lessons from these pioneering projects can help transform studio ceramics into more sustainable, regenerative and circular practices? The analysis of the case studies reveals the interconnected elements of materials, meanings and competencies.

MATERIALS. The sustainable sourcing of local and repurposed materials is a notable development in pottery practices that takes makers out of their studios and connects them with other industries. Whilst the environmental advantage of fetching wild clay demands scientific validation (e.g. through LCA studies), implementing industrial symbiosis in ceramics (Howard, 2020) has clear benefits (which should also be assessed). This 'system thinking' approach brings synergetic efficiency in the wider manufacturing sector, well beyond the confines of ceramic workshops (e.g. in the construction industry).

Beyond the measurable impact of each project, the case studies show that it is possible to establish new relationships between material supply and demand, transforming waste into a resource and disrupting established making methods and material flows while building on the skills and knowledge of studio ceramics. These projects demonstrate such innovation is possible and even available to individual makers, studios and collectives. Other manufacturers can take up on these methods and expand their benefits but a more radical, effective and in many ways easier approach would be for clay and glaze material suppliers to learn from them, take advantage of waste as a resource and utilise their established commercial and distribution chains to make it available to studio makers of any size. Environmental labelling can then help buyers make informed choices.

MEANINGS. Sustainability has the potential to shift studio ceramics from a value system focused on craftsmanship, tradition and design to one that prioritises ecological stewardship for future generations, addressing challenges such as resource limitations, water scarcity, pollution and contamination. The case studies show us how attractive products with refined design qualities can emerge from practices shaped around environmental and community regeneration. Creative expression can thrive in the technical challenge of achieving accomplished forms and refined craft aesthetics by utilising unconventional methods and resources. The complex interrelation of tradition and innovation in craft practices has often privileged narratives of conservation of skills and cultural heritage. However, scholars have noted the role craft plays in industrial innovation (Adamson, 2013) and the reliance of craft practice on other industries (Knott, 2015). Placing innovation for sustainability and regeneration at the core of studio ceramics would be aligned with contemporary readings of the history and theory of craft.

COMPETENCIES. Environmental education is crucial to raise sustainability literacy among makers and other stakeholders. New knowledge and understanding can help focus on regenerative practice and increase the demand for new material and technological innovation. Rethinking the cultures of making outside the confines of studio workshops offers creative potential and the chance to foster a more circular, fair, and sustainable society. In practice, efforts to bring more research and formal education in the field of craft ceramics should be prioritised if we want to reach a more informed, critical understanding of both issues and solutions. Education in sustainability science should not simply aim to instruct makers on the consequences of their individual actions but empower all stakeholders (and ideally all consumers of their products) with the knowledge required to reform current systems of production and consumption, finding alternative, sustainable routes for manufacturing goods and expressing creativity.

Conclusions

Informed by literature, practice and ethnographic experience of British pottery studios, this paper looked at the issue of sustainability in craft ceramics by identifying some key challenges to innovation. The lack of scientific research represents an important issue for practitioners willing to make informed choices. But even with more reliable data, developing and implementing solutions requires sufficient understanding of sustainability science. Literacy in this area is especially critical for manufacturers, whose processes not only contribute to environmental harm but also fail to adopt regenerative practices that could foster positive impact. Sustainability education should be an integral part of potters' training and not an afterthought confined to the self-teaching of a few individuals.

Practice theory can help identify and develop more radical approaches to achieve sustainability in craft ceramics. Maximising efficiency and reducing material waste and energy consumption should be encouraged in any studio process. But the new methods, materials and technologies required for a more fundamental shift in making practices can be achieved by working closely not only with ceramic suppliers, distributors and manufacturers, but with a wider local industrial and commercial ecology.

Pragmatically, efforts to educate both established and aspirant potters in sustainability science will be central to create a snowball effect towards more demand for research and innovation in the sector, to make more informed choices that can gradually reform current practice and, beyond that, to inspire the shift of paradigm that is required to adopt truly sustainable processes.

This positioning paper offers first reflections on the current state of the issue based on the analysis of three examples. Its originality lies in using practice theory to celebrate the lessons learned from the case studies not (only) to inspire other makers to follow in their steps but to show the importance of systemic thinking and collective actions to reform current practice and make ceramic manufacturing more environmentally sustainable.

A deeper dive into the nuances of practice theory would likely illuminate and clarify some of the initial points made here. Further LCA studies and reviews are needed to increase the resolution of the analysis of environmental impacts of craft ceramics, to help us identify priority actions and most effective solutions. More research is needed on how to create industrial ecosystems and local ecologies of waste in which studio ceramics can play a role in reducing waste streams while offering new creative opportunities to makers.

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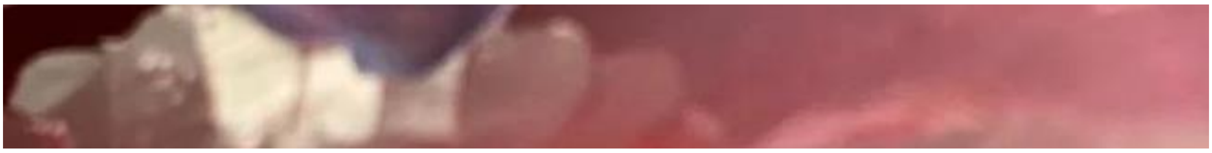

Shifting Horizons: Exploring the intersection of landscape & human experience in the evolving realm of sustainable glassmaking

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Introduction

This paper explores the relationship between landscape and human experience in the evolving realm of sustainable glassmaking. The relevance of this paper is set out within the conceptual framework of the Anthropocene (Crutzen, 2000), a period that describes when human activity started to have a significant impact on the planet's climate and ecosystems. The discussion will be extended to how this has had a wide-ranging influence on material culture, including creative craft disciplines such as glass art. The case for sustainable glass making will be set out and discussed and a series of selected glass makers and their works will be showcased to demonstrate a response to this theme. Finally, this paper will be summarised by drawing upon these selected examples to express a series of key findings. In amplifying these works and voices it is hoped that this paper can stimulate meaningful discussion around sustainable approaches to glass making, as well as highlighting, the important role of glass art as an important medium for environmental commentary.

The connection between place, the natural world and landscape within art glass practice is an important driver for many glass makers, who are driven by a deep connection to place and a belief that the place where something is made can influence the production of a crafted object. These objects often carry embedded material knowledge, reflecting the environment from which they emerge and are inherently linked to the natural world and the landscapes in which we inhabit, works made in this way can issue a collective commentary on the impact of humanity on our natural world.

This paper will discuss the interconnectedness between humans, nature, landscape and crafted objects - that can be created to illustrate this relationship. Crafted objects are intimately linked to the contexts from which they emerge and have the ability to tell the story of their origins through the materials they are made from. Firstly, it is important to acknowledge that our environments and landscapes have always changed and are constantly in a state of flux. We are all painfully aware of the impact of climate change on our natural world, melting polar ice caps, sea levels are dramatically changing and rivers and seas that are cutting through, creating erosion and the deposition of land, causing widespread flooding and damage. In turn, the issues of forest fires, adverse weather events and other natural disasters are dramatically changing our landscape. The impact of manmade interventions, and deforestation for industrial and agricultural developments continue to damage our natural world – we are most definitely living through a climate crisis. It is important and evident that makers carefully examine their own creative craft practices in consideration of this, and in a direct response to climate change.

Methodology

This paper employs a methodological approach that is influenced by two critical elements, the conceptual framework of the Anthropocene as defined by Crutzen, in 2000 and the United Nations Sustainable Development Goals established in 2015. However, it important to firstly draw upon the definition and notion of landscape which has inspired this paper, the writings of Tim Ingold will be used to initially frame this approach. In his text on The Temporality of the Landscape, Ingold (1993) adopts a dwelling perspective of landscape, to view it as an: *enduring record of – and testimony to – the lives and works of past generations who have dwelt within it, and in doing so have left there something of themselves (Ingold, 1993, p.153).*

Ingold describes how: *the landscape tells - or rather is - a story. It enfolds the lives and times of* *predecessors who, over the generations, have moved around in it and played their part in its formation. To perceive the landscape is therefore to carry out an act of remembrance, and remembering is not so much a matter of calling up an internal image, stored in the mind, as of engaging perpetually with the environment that is itself pregnant with the past (Ingold, 1993, p.153).*

It is important to extend this by connecting this to the approach of makers who choose to tell the stories of the landscape that we inhabit through their work. And who in turn acknowledge the impact we have on our landscape and the responsibility we have to climate action. As discussed, the Anthropocene *is a* conceptual framework that states that human activity has fundamentally influenced and irrevocably changed our climate and environment.

Climate change has brought into sharp focus the capability of contemporary human civilization to influence the environment at the scale of the Earth as a single, evolving planetary system… The concept of the Anthropocene, proposed by Paul Crutzen was introduced to capture this quantitative shift in the relationship between humans and the global environment (Steffen, Grinevald, Crutzen, McNeill 2011, pp.842-843).

In turn, the concept of the Anthropocene is deeply interconnected with the United Nations (2015) Sustainable Development Goals (SDGs), addressing many of the most critical challenges our planet faces today. The concept of the Anthropocene directly impacts several SDGs, particularly those related to the environment, in particular SDG Goal 13: Climate Action. In addition, the Anthropocene underscores the unsustainable nature of current production and consumption patterns. SDG 12 which focuses on ensuring sustainable consumption and production patterns, which directly relates to creative craft practice and making - this is a crucial goal to use to mitigate the impacts of the Anthropocene. The recognition of the Anthropocene highlights the extensive human impact on the planet and urges the immediate implementation of the SDGs.

Since their publication in 2015, the world has reflected upon and used the UN Sustainable Development Goals as a target to revise our actions and to direct our research drivers with an aim to implement them by 2030. This call to action is a collective, universal wake-up call: to end poverty; protect the environment; achieve gender equality; ensure health and well-being and ensure peace and prosperity for all. But what does this mean in terms of Art Glass? The far-reaching effect of these goals when viewed through the lens of the international Art Glass movement is an engaging and exciting space to examine. Understanding how the goals can or have been applied to contemporary Art Glass practice, education, and community is an important inquiry for the sector (Rothwell, Kelly, 2023, p.183).

This is an engaging and exciting space to examine within the field of glass art. With climate change and action at the forefront of our minds, it is apparent that this subject is a motivation to glass art. In 2021, we witnessed the *European Glass Context* theming its celebration of art and studio glass around the UN Sustainable Development Goals and citing sustainability as its main theme. And in 2022, the *Power of Glass Craft Scotland* conference was held in Edinburgh, it focused on the SDG's and discussed a range of sustainable practices in glass art. This event was a landmark for the sector and has fuelled further debate and study around sustainability in glass art.

When it comes to material extraction and exploitation, it is important to discuss the methods employed by many glassmakers, who wish to explore material reuse within their creative practice. It is apparent that there is a collective approach, which is drawn into focus when a maker selects their materials. For example, when a maker compares (in terms of carbon footprint) virgin glass to recycled glass the environmental impact benefit of reused or recycled glass is an essential material for sustainable creative production. Great care, consciousness and critique are needed when selecting materials and techniques to work with especially as glass and the process of glassmaking is not always an easy companion for ecological debate. The primary ingredients in virgin glass, such as limestone, silica sand and soda ash, are indeed natural.

Although most people think of glass as a man-made material, it is found in many forms in the natural world. Volcanoes spew molten rock, lightning strikes desert and beach sands, meteorites pound the earth, and sea sponges and microscopic organisms inhabit the waters. All of these things—and even lunar soils—are materially related to the man-made glass that we use every day (Corning Museum of Glass, 2024).

However, the glass type that is most commonly used in creative practice is generally a manmade material. The industrial production of virgin glass can be viewed as a form of extraction (and exploitation) of natural resources and materials. As discussed by Ravenhall (2020): *Heating sand to its very high melting point of 1,700 Celsius takes a lot of energy*. Additionally, the process of making virgin glass uses a significant amount of water and contributes to air pollution. Sulphur oxides are emitted during melting, and if gas is used for heating, nitrogen oxides are also released. All these factors, issues a serious call for glass makers using virgin glass to consider their actions. Demonstrating the urgent need for new sustainable and alternative approaches to glass making and highlights the importance of using recycled glass in creative practice.

As discussed by Rothwell and Kelly: *Historically, glass recycling can be traced back to the First Millennium AD. Today, glass is viewed as a sustainable material as it is made from naturally occurring materials, and if properly cleaned and sorted can be infinitely recycled. Unfortunately, the recycling and processing of glass is complex. Contamination and sorting are a huge problem; most glass is only considered for single-loop recycling, with the majority becoming aggregate within road surfaces. When processed and disposed of in the right way, glass can offer a viable alternative to synthetic materials, offering sustainable products that actively reduce our impact on the environment.... Though glass is inherently recyclable, it is, however, an energy-expensive industry, that often relies on imported raw materials, and thus requires reconsidering to make it a viable outlet for creatives of the future (Rothwell, Kelly, 2023, p.183).*

Recycled glass addresses many of the environmental concerns associated with virgin glass production. Since glass can be recycled indefinitely without any loss in quality. This means fewer natural resources are extracted from the environment. In regions where coastal erosion is a concern, this reduces the need to remove sand from beaches to make glass. As discussed by Ravenhall: "*Recycling glass is more efficient at every step along the production process. Every 1,000 tonnes of glass that gets recycled can lead to savings of: 1,000 tonnes of waste diverted from landfill,1,200 tonnes of raw materials saved*, *314 tonnes less of CO2 emissions* and *345,000 kWh of energy savings. It can be hard to picture what 1,000 tonnes of recycled glass would look like. Instead, think of one glass bottle. Recycling that alone can save enough energy to power a 100W lightbulb for nearly an hour, or a typical computer for 20 minutes" (Ravenhall, 2020).*

Although concise, this section has clearly outlined the methodological approach of this research paper and has set out clear research methods, stages, and techniques that are prevalent within the field of glass art. The next section builds on this foundation and will discuss the key findings synthesised in this study. This discussion will not only present the results but also analyses their implications and relevance to both the academic community and the broader field of glass art.

Results: Key findings

In recognising sustainable models of practice are evident in glassmaking and in discussing their importance within the field of Art Glass, it is clear that a key finding is the variety of glass artists that choose to prioritise sustainability in their work, through the reuse or recycling of glass or the use of low impact processes or techniques that are more sustainable. As previously discussed, sustainability is gaining considerable ground within the glass art community and many makers are pioneering the use of recycled and sustainably sourced materials to make their work (a range of whom will be discussed in this section). In addition, is evident is that many glass makers also draw upon their deep connection to place or landscape as a means to illustrate this approach. Exploring the inherent properties and origin stories of the materials they use (glass), as well as drawing upon distinct social, political and/or environmental commentary through the medium of glass

The small batch, limited edition and one-off production runs of art glass making are not over-consumed, they are a conscious, deliberate and intentional acts. Production is closely connected to the maker and they often make to order and take great care and time over their work. glass art inherently contributes to the slow movement, as many glass artists are genuinely interested in how to reduce their studio waste and save money, especially given the current energy crisis. glass art production creates artefacts of legacy that will outlive their owners but most importantly, it can become activated as a vehicle for glassmakers to voice their concerns of the sustainability issues we face, in the form of craft-activism. Sustainable art glass production can be viewed as a vital antidote to the environmental issues we face, in the form of craft-activism. However, glass makers are not just driven by ecological concerns but also by an acknowledgement of the unique qualities of materials and resources sourced from specific regions and places. Often inspired by darker histories, linked to past historical and cultural events - such as colonialism, material extraction, deforestation, and the exploitation of natural resources. In order to explore the impact of humanity on the natural world through glass making practices. A series of short case studies will now be discussed, all of the selected glass makers explore human experience, landscape and the impact of climate change on the natural world through their glass work.

Jessamy Kelly (the author of his paper) is a glass artist and educator based in Edinburgh, Scotland. Her work is concerned with the conceptual framework of the Anthropocene, acknowledging that human activity has fundamentally influenced and changed our climate and environment (see Fig. 1).

Fig 1. Dr Jessamy Kelly (2019) *Waste Glass Landscape*. Recycled bottle glass, kiln cast glass.

Kelly (2024) describes her work: *In our experience of place and landscape there is an immediacy to what we believe is a natural view and we are in awe. However slowly over time this landscape has been changed, deforested, developed, scarred, melted and altered. Landscape is in a state of constant flux, ever changing, yet a sense of place remains with us in our minds. Through the medium of glass, I use this approach to represent the changing state of landscape. This work asks us to view a moment in time to question and capture what we have lost through human activity.*

Kelly aims to represent how landscapes are constantly changing, her work inspired by glacial, melting ice forms is a direct environmental commentary on climate change. This work presents the land moving as the glacial landscape is formed and then set, it continues to reset and move as the earth moves very slowly over time, referencing the melting of the polar ice caps. Her series of fused glass work entitled *Coast* is based on the tidal lines created by the sea, they change every day with the rhythm of the sea, this series draws on the idea of climate change and rising sea levels.

Gregory Alliss is a PhD candidate at Edinburgh College of Art examining contaminated glasses such as recycled CRT glass from Cathode Ray Tubes, the main component of older style televisions. He creates eerie cloud-like formations which feature a stormy horizon line or captures manmade patterns into the surfaces of his kiln cast glass work. These patterns embody the movement of molten glass and the intricate information that flows across the object's optical boundary (see Fig.2). Gregory’s work invites exploration, serving as a portal to a realm where the subtle nuances of the material can be closely examined. He has since broadened his investigation to include the creation of glass art using unconventional raw materials such as fluorescent tubes, container glass and window glass.

Fig 2. Gregory Alliss (artist) and Shannon Tofts (photographer) (2023) *Downburst*. Recycled CRT Glass, kiln cast glass.

Carrie Fertig is a Scottish based performance artist that primarily works in glass. She is a member of Applied Arts Scotland Closing the Loop – working group centred around zero waste, the circular economy, alternative sustainable materials and the application of sustainability tools and practices in the studio toward zero carbon. One of the ways Carrie works sustainably is by making multiple artworks out of the same materials. She works in performance and video (as well as sound, virtual reality, installation, and sculpture).

Much of Fertig's practice is about place making, creating safe environments for her audiences where they can reflect upon themselves, she uses flameworked glass as a medium to create these spaces, which can be seen in her work. Her project, the Health of the Sublime (2024) is a Creative Scotland funded project that maps the lived experience of wellbeing through the lens of climate change and is partnered with Mearns and Coastal Healthy Living Network a charity whose remit is to support wellbeing for participants aged over 50+ in and around Kincardineshire, Scotland. Her aptly named project: Plummet (2021) was commissioned by the UNFIX Festival an online climate crisis performance and art festival that happened simultaneously in Glasgow, Tokyo, Barcelona, and New York in 2021. She created a live performance with her glass that included an ending credit soundscape was comprised of crowd sourced sounds from around the world including a Sri Lankan rainstorm, French geese, Maryland bees, German frogs, and many others (see Figure 3). She describes in detail her glass work created for this performance: *To ensure the work inspired by my experience is less impactful upon the planet, most of the components were recycled. Thousands of hollow glass musical icicles made for a previous project were transformed into a plummet of symbolic melting of ice.*

Fig 3. Carrie Fertig (2021) *Plummet*. Recycled flameworked Glass.

Shaun Fraser is a Scottish artist based in London, his work comments upon notions of identity, links to landscape and connections with place. The Scottish Highland landscape in which he was brought up is a source of inspiration for his work, he views landscape as a part of his notion of self. Within his work there is a certain sense of devotion which he attaches to this topographic work which is elemental. His practice questions how the landscapes, spaces and places which we inhabit form us and can be translated through personal engagement, using one's own memory as a principal source. Through this he acknowledges that memories of landscape, recalled with clarity when first encountered, can over time shift to become completely obtuse and non-linear, they become part-remembered-part-imagined places. Much of his most recent work is an attempt to recall a fleeting sense of a specific place and time that he has experienced. In discussion of his work, he describes his approach (Fraser, 2024): *I often find that I am as interested in the idea of a place as the place itself and think the actual and the imagined versions are equally valid. What I attempt to do through my practice is to tap into some of that disposition. Including peat and local soils into my sculpture gives the work an innate link to the landscape, something which I believe to be very important in my practice, the ability to evoke that sense of place.*

Inspired by the Flow Country, a protected peat bog area in in the Scottish Highlands. Fraser has been working with the Flow Country Partnership, to create work that visualises the damage that has been done to Scottish peat bogs. The Flow Country Partnership is preparing to apply for world heritage status for this site (People Are Culture, n.d.).

Fig 4. Shaun Fraser (2020) Moine, Flow Country, Caithness & Sutherland. Kiln cast glass.

Pinkie Maclure is a multidisciplinary Scottish artist, who believes that our present is haunted by our past and we have more in common with our ancestors than we may know. Using stained glass installations, she makes intimate work that examines today's big issues, such as addiction, insomnia and our relationship with nature. Maclure (2024) describes how she uses glass as a metaphor for darker histories in her work: *the distinctively chaotic nature of stained glass to express deep anxieties - often with dark humour - exploiting the tension between the sacred and the unexpected, at a time when the end of the world feels closer than ever*.

Through her work she explores issues relating to addiction, insomnia, women's rights, sustainability and environmental issues. Pinkie sees the unique medium of stained glass as fragmented and uses this to express the deep anxieties and tensions present a range of socio-political narratives in her work (see Fig.5).

Maclure (2018) describes the inspiration for her artwork Self-Portrait Dreaming of Portavadie: *We used to spend our summers at my grandad's cottage in Portavadie, a little-known, idyllic and remote corner of the west coast of Scotland. There was no electricity or running water, but I remember those days as the best of my childhood. In the mid-1970s, the government sold the surrounding land to a company for the building of oil rig platforms. Portavadie was completely destroyed. The company was heavily subsidised, but their designs were outdated, and no orders came. The company went bankrupt, leaving the taxpayer to pick up the repair bill of many millions of pounds. Portavadie was left derelict for decades, described in the press as: the most expensive man-made hole in Europe.*

Fig 5. Pinkie Maclure (2018) Self-Portrait Dreaming of Portavadie. Stained Glass in Light Box.

Inge Panneels is a glass artist and researcher based in the Scottish borders; she is also a Lecturer in Digital Media at Edinburgh Napier University. Her research is based on an interest in 'mapping in art' which prompted a theoretical investigation in how artists are charting climate change in the Anthropocene, the subject of her PhD research project (2019). Her work entitled *Claude Glass*, references a technique invented by the French painter Claude Lorrain (2021), who used black glass, or mirror to frame the landscape and was used by many landscape painters (see figure 6). A further series of work, entitled the *Buchan Way* was informed by the work of Scottish writer John Buchan.

Fig 6. Inge Panneels (2021) Claude Glass. Kiln cast glass.

With an avid interest in mapping, she created a published paper and case study of place-based material craft practices, as a way of Mapping the Anthropocene. She created a study on Atelier NL, a creative design studio based in the Netherlands that is focused on the connection between materials and their source of origin. In this paper, Panneels (2019) argues that: *mapping* as a methodology can support localised production, as exemplified in the case study of the design studio Atelier NL which marries contemporary design sensibilities with traditional glass and ceramics craft-making techniques. The paper puts forward the argument that by paying attention to local ecosystem services through mapping, place-based design solutions can be developed.

Jeff Zimmer is Scottish based glass artist, he creates works that explore the complexity in human connections, that engage with the material and symbolic properties of glass. He is interested in the sensual experiences of mystery, light and shadow and often creates work that respond to the Scottish landscape. After returning from a residency at North Lands Creative Glass, he started making work that looked like *Interventions in Landscape*, this became the title of a series of work that used many layers of glass that captured a sense of the volume of open space that he had encountered during his residency in the broad, open expanses of the highland landscape. He describes the ideas behind this series: *This work deals with the history of interventions in the Scottish landscape. At the time the then-novel and controversial wind turbines started to make their presence known in the Scottish landscape. People would look past fields dotted with sheep and complain about the wind turbines in the distance and how they were ruining the landscape. It made me think of how the imposition of large-scale sheep grazing has had significant negative effects on soil quality and biodiversity and led to the devastation of swathes of Scottish communities in the Highland Clearances. Yet today, we view the sheep as a beloved symbol of Scottish rural life.*

In juxtaposing the sheep in the foreground with the wind farm in the background (see 7), he highlights the continual human reshaping of the Scottish landscape and question where we place value on what we see and experience.

Fig 7. Jeff Zimmer (2006) Interventions in Landscape. Painted sheet glass.

Discussion: Contribution and impact

This paper has discussed and showcased a range of glass makers and artists whose creative practice collectively responds to the interplay between landscape and human experience. Using the framework of the Anthropocene and the impact of humanity on our world, to illustrate a range of glass art works that respond to the natural world we inhabit. The contribution and impact of this paper is twofold in sharing the work of these artists collectively in this paper it aims to amplify their voices, to inspire a meaningful discussion on sustainable approaches to glass making as well as revealing a deeper understanding of the interconnectedness between humans, nature, and the things we create.

It is important within this final discussion to consider the rich fertile ground and shared context for many of these Scottish based glass artists, who have studied, worked or lived in Scotland. The work of Craft Scotland, a national agency for the development of craft is key to this final discussion. Irene Kernan (2014) the director of Craft Scotland states: *The climate change crisis needs urgent attention and action. Individually at Craft Scotland we all share a commitment to creating a working environment and culture that will reduce our environmental impact. As a national agency we also have an important role in raising wider awareness of the innovative and effective working practices of makers from across Scotland and showing where they have impact.*

Through their collaboration with Creative Carbon Scotland, Craft Scotland have founded: The Green Crafts Initiative (GCI) in 2014. Makers and craft organisations across Scotland can join the Green Crafts Initiative, which offers support and guidance to those committed to minimising their environmental footprint. The impact of this initiative on Scottish based craft practice has had a clear and evident impact on the creative craft community in Scotland.

In summary, to draw together this paper, it is important to highlight the profound role of glass art as a medium for glass makers to articulate their environmental concerns. In addition, the impact of their work is a powerful form of craft activism, in its strong advocacy for climate action. This approach, particularly through creative glass practice, represents a powerful intersection of art, craft and environmental advocacy that emphasises climate injustice. Finally, this article leverages the unique capabilities and characteristics of glass art to communicate and urges an immediate action to the field and beyond to respond to creative practice through climate action.

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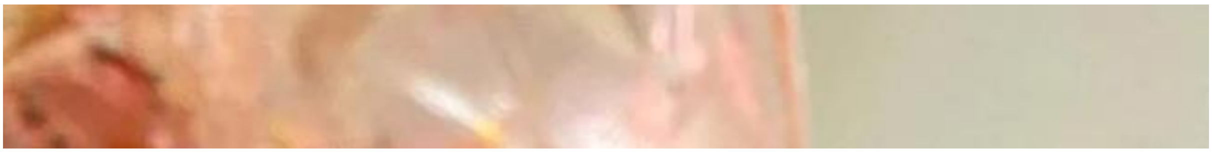

Rooted in Place: Crafting Sustainability Through Locally-Embedded Design Education

Dr Lara Torres

Keywords: Sustainable Educational Practices; Place-based Approaches; Regional Craftsmanship; Material-led Pedagogies; Cultural Heritage

Introduction

This paper addresses the need for alternative educational models that embed sustainability into the core of the learning process. It explores how place-based approaches and material-led pedagogies, which draw on local knowledge and resources, can be powerful tools for fostering sustainability in design education. By integrating Indigenous and Local Ecological Knowledge (ILEK) into the curriculum, educators can create immersive, context-specific learning experiences that not only reduce the environmental impact of long-distance material transport but also foster a deep appreciation for local ecosystems and cultural heritage (Mellegård & Wiebren, 2020).This research aims to illustrate how these approaches can contribute to more equitable, resilient, and sustainable educational practices that transcend geographical boundaries.

I teach on the MA Fashion Artefact, postgraduate program which sits in the School of Design and Technology (SDT) at London College of Fashion. I was invited to develop a low-residency version of the course, which sparked my interest in place-based pedagogies and methods for teaching and learning. This research explores potential alternative educational models incorporating local knowledge, place-based and material-led pedagogies, to foster sustainability in design education to reduce environmental impact.

In the present Anthropocene epoch, which has been characterised by significant ecological changes driven by human activities (Crutzen, 2006), the need to rethink and restructure education, particularly within the design disciplines, has become increasingly urgent. The Anthropocene is not just a geological era but also a call to action—a recognition that how we live, produce, and educate must change to ensure a sustainable future. This paper proposes that material-led low residency studies offer a promising paradigm for sustainable educational practices, integrating ecological, social, and economic dimensions into a holistic learning approach.

The challenge lies in the paradox of our current practices: we utilise elements from nature to sustain our civilisation, yet these same processes contribute to environmental degradation (Bak-Andersen, 2018). This contradiction underscores an urgent need for a transformative approach to the processes and methods by which we teach and make fashion. A re-evaluation of our manufacturing practices is imperative to mitigate their adverse environmental impacts and develop more sustainable production modes. This paradox is especially evident in industries like fashion, where the ecological impact remains exceptionally high despite significant technological advancements and increased awareness of sustainability issues (Lehmann et al., 2019).

Methodology

The research employs a combination of literature review, case studies, and analysis of a range of pedagogical frameworks to provide a nuanced understanding of how these approaches can transform design education and promote sustainability.

Rationale for Method Selection

The selection of methods for this research was driven by the need to capture the complexity and context-specific nature of place-based, material-led design education. Case studies were chosen because they represent examples of implementing these changes or circumstances that can accommodate this type of change to locally embedded design education. The literature review provided insights from existing literature, curricula, project reports, and institutional policies, while thematic analysis helped identify key themes and patterns across different case studies.

Challenges and Limitations

Implementing material-led and place-based approaches in design education comes with several challenges. These include institutional resistance to change, resource constraints, and the difficulty of scaling these approaches to larger educational settings. Additionally, integrating local materials and knowledge into the curriculum may require significant adjustments to existing teaching practices and resources. However, these challenges also present opportunities for innovation and collaboration, particularly in low residency programs where students are embedded in their local communities.

Results: Key Findings

Material-led Pedagogies

Over the past ten years, different versions of a material-focused design approach have been gradually developed by various design professionals and researchers, a process in which the material plays a fundamental role from the beginning of the design process. Most researchers describe this process as material-based, material-driven, or material-led (Karana et al. 2015, Van Bezooyen 2013, Hansen 2010, Oxman 2010, Bak-Andersen, 2018). Material-led pedagogies represent a shift in design education, where the material is not merely a medium but a co-participant in the creative process. This approach aligns with the theoretical framework of New Materialism, which posits that matter has agency and plays a crucial role in shaping human actions and decisions. Mette Bak-Andersen (2018) highlights that material-driven design processes start with the material's properties, potential, and limitations. The designer's role is to explore, manipulate, and understand the material, allowing it to inform the design process from the beginning. Karana et al. describe how 'over time, the designer who takes an MDD (Material Driven Design) approach is expected to become master of a given material: they will know how the material behaves under different circumstances or how it reacts when subjected to different making techniques or manufacturing processes' (Karana et al. 2015).

MDD contrasts sharply with traditional design methodologies, where materials are often selected after the design concept has been fully developed. In a material-led process, the exploration of materials becomes a source of inspiration and innovation. Designers are encouraged to engage in hands-on experimentation, where the material's physical properties influence the final product's form and function. This iterative process, where design and material interact dynamically, is central to the philosophy of material-led pedagogies.

This approach is taken in the MA Fashion Artefact. I teach on the course to a cohort of mostly international students from a very diverse disciplinary background, such as jewellery, product design, and fashion design among others. Craft is at the core of this designer-maker course, and many MA projects tend to be material-led. Based in a studio environment, students share studio space and have communal access to a series of workshops (jewellery, leatherwork, mould making and casting, etc.). This sharing community is central to the course's essence. Students are often invited to explore, learn and become skilled in specific materials and techniques. According to Richard Sennet (2008), in the traditional workshop environment, 'craft arises out of face-to-face interactions sustained over extended periods in the workshop space, where neophytes can watch and imitate expert craftsmen, receive instruction and correction, and learn by doing'. This kind of learning, what educational psychologists call 'situated cognition', 'occurs when the learner is embedded within a community of practice, such as a workshop, where the embodied practices of the artisan are visible, and learning is based on observation and imitation' (Fowkes, 2020). This process permeates the studio-workshop culture through the shared environment between technical staff and students and between cohorts of first and second-year students.

Therefore, when translating this context to an online low residency program, the shared studio space is not readily available online - meaning less cross-contamination of ideas, techniques and material knowledge happens. I believe this environment can likely be replaced by local communities and their technical expertise that students can connect with if studying in their local environments but supported by online curricula and low residency study pedagogies.

A material-driven design process helps students understand how to approach local materials and create designs based on this knowledge. In "When Matter Leads to Form: Material Driven Design for Sustainability" (2018), Bak-Andersen outlines a three-step process for Material Driven Design (MDD):

1. **Material research**: This includes evaluating circularity, sourcing, composition, historical context, value, and hands-on exploration.
2. **Material manipulation and design**: Materials are adjusted to enhance strengths, address weaknesses, and engage in 3D sketching.
3. **Product development**: Focuses on integrating form and function, culminating in the prototype presentation.

Material-led pedagogies represent a significant shift in design education, emphasising the active role of materials as co-creators in the design process. This approach, rooted in New Materialism, not only redefines the relationship between designer and material but also incorporates a strong sense of place, recognising that materials are deeply embedded within their local contexts. Bak-Andersen's Material Driven Design (MDD) process exemplifies how understanding materials' origins, properties, and cultural significance can lead to more sustainable and innovative design practices. By integrating place-based considerations, this approach encourages designers to explore and manipulate materials with an awareness of their ecological and cultural contexts, thereby fostering a design process that is materially informed and attuned to the local environment. This focus on the interplay between material and place enriches the educational experience, guiding designers towards creating sustainable, contextually relevant solutions, and deeply connected to the communities and environments from which they arise.

Sustainable Educational Practices

Sustainable educational practices are those that not only teach sustainability as a concept but also embody it in the methods and processes of education itself. This means creating curricula that integrate ecological, social, and economic sustainability into every aspect of the learning experience. In the context of design education, this could involve using sustainable materials, promoting ethical manufacturing practices, and encouraging students to think critically about their work's environmental and social impact.

As Kim and Lee (2022) emphasise in their study, 'Sustainable fashion design education aims to educate students on how to explore fundamental values and possibilities of sustainable development, recognise social issues, and find solutions to problems beyond simply educating how to implement sustainable fashion design.' They argue that a well-rounded education on sustainability holds future-oriented value by fostering a shift in perception among students, who will become tomorrow's design professionals, enhancing both their design skills and their understanding of sustainable practices. The literature increasingly acknowledges that the integration of sustainability into education demands more than superficial adjustments to existing curricula (Junestrand et al., 2024) and that educators have been proactive in integrating *Education for Sustainable Development* (ESD) initiatives into HE fashion education in the last decade (Agarwal, 2020; Armstrong and Le Hew, 2013; Baytar and Ashdown, 2014; Jestratijevic and Hillery, 2023). There is a pressing need for a paradigm shift in educational structures and delivery methods. This shift entails moving away from standardised approaches and adopting models that are context-specific, responsive to local needs, and rooted in the realities of the communities they aim to serve. Burns et al.'s (2019) *Model of Sustainable Pedagogy* emphasises content co-creation, diverse perspectives, participatory processes, and context-specific learning.

Place-Based Education Approaches

Place-Based Education (PBE) is an umbrella term for pedagogical practices that prioritise experiential, community-based, and contextual/ecological learning to cultivate greater connectivity to local contexts, cultures, and environments (Gruenewald, 2003; Smith, 2002; Sobel, 2004; Orr, 2013). It incorporates the meanings and the experiences of place in teaching and learning, which can extend beyond the walls of the school (Yemini et al., 2023).

Place-based education is a pedagogical approach that emphasises the importance of local context in the learning process. It involves teaching students about their local environment, culture, and community and encouraging them to apply this knowledge in their work. Place-based approaches have been shown to foster a deeper connection to the material being studied and a greater sense of responsibility towards the local environment and community.

PBE regained significant attention with the early 2020 outbreak of the COVID-19 pandemic, which caused large-scale school closures globally and forced the rapid adoption of alternative learning environments, including teaching and learning outdoors, and learning from home (Yemini et al., 2023).

In the context of design education, place-based approaches can involve using local materials, collaborating with local artisans, and studying local craftsmanship traditions. By doing so, students learn valuable skills and develop a greater appreciation for the cultural and environmental significance of the materials and techniques they are working with. This approach also supports the preservation of cultural heritage as students learn to value and maintain traditional practices.

In reviewing the literature on place-based education (PBE), the following relevant points can be gleaned:

PBE is often implemented in various subjects, particularly environmental studies and science, but its application in other areas like arts, literacy, and social studies remains limited (Yemini et al., 2023). The literature also points out that while PBE is often linked to improving students' environmental awareness, its broader impacts, such as fostering social justice, community engagement, and decolonisation, are equally significant but less frequently explored. One key framework for understanding PBE is Ardoin et al.'s (2012) model which categorises PBE into four dimensions: biophysical, psychological, socio-cultural, and political-economic. These dimensions provide a comprehensive view of how place influences education, highlighting that the concept of place goes beyond mere geography, encompassing cultural, social, and economic factors.

This review identifies key challenges in implementing Place-Based Education (PBE), including the significant need for lecturer preparation, resource allocation, and active community involvement. Despite these obstacles, PBE remains a promising approach, fostering connections between students and their local environments, promoting sustainable practices, and enhancing community well-being. A study cited by Structural Learning (Main, 2024) suggests PBE also strengthens ecological integrity by deepening students’ appreciation for the natural world. However, existing research primarily focuses on school-level education, with limited exploration of PBE in higher education. This gap warrants further investigation, which exceeds the scope of this paper, where we have only begun to explore PBE’s potential.

In design education, incorporating PBE could mean engaging students in projects that utilise local materials, collaborate with local artisans, and explore traditional craftsmanship. This not only enriches students' educational experiences but also supports the preservation of cultural heritage and promotes sustainable design practices deeply rooted in the local context.

The findings of this research highlight the transformative potential of material-led and place-based approaches in design education. The case studies that follow demonstrate how these approaches can intensify students' connection to local materials and craftsmanship while also promoting sustainability and cultural preservation.

Case Study 1: Artefact & Local Identities

In 2018, the MA Fashion Artefact course leader at London College of Fashion, Dai Rees, curated an exhibition titled 'Why-What-Who' as part of the Venice Biennale of Architecture's parallel program Design.Ve - Biennial Design Walks through Venice. The exhibition showcased a wide array of works from MA Fashion Artefact alums, spanning a decade of creative exploration. The exhibition went on to tour China and Argentina. One of the standout projects from the touring exhibition was a commissioned project, a collaborative effort between course alums and local designers, Daniel Ramos Obregón from Bogotá and local designer-maker Juliana García Bello from Tierra del Fuego. Their work (See Figure 1), featured in the exhibition at the Museo Nacional de Arte Decorativo in Buenos Aires, Argentina, in 2019, profoundly explored cultural identity through speculative objects, weaving a narrative that connected regional craftsmanship and cultural heritage.

Cross-Cultural Dialogue Through Design: The Colombian Poporo and Argentinian Mate

Fig 1. Gonzalo Valenzuela (2018) Speculative objects, Daniel Ramos Óbregon in collaboration with Juliana García Bello for 'Why-What-Who' exhibition at the Museo Decorativo de Buenos Aires, Argentina

Obregón and Bello's collaboration highlighted the power of material-led and place based-design to foster cross-cultural understanding and dialogue. Their project focused on two culturally significant objects: the Colombian *Poporo* and the Argentinian *Mate*. The *Poporo*, an indigenous object associated with the traditions of the Kogi people of Colombia, symbolises maturity and status (Tairona Heritage Trust, 2008). The *Mate*, a traditional vessel used in Argentina to drink the herbal tea known as *Mate*, is a cultural cornerstone that reflects the country's social rituals and communal identity (Sarreal, 2023). By choosing these objects, the designers sought to explore the relationships between their cultural heritages while also addressing the specific regional craftsmanship associated with these artefacts (Rees, 2019). Through this cross-cultural lens, the project illustrated the commonalities and differences between the *Poporo* and the Mate. The designers created hybrid speculative objects that merged elements of both, encouraging an open dialogue about the cultural significance of these artefacts in their respective contexts. This approach allowed them to engage with their cultural identities critically, questioning how material culture and craftsmanship are deeply tied to notions of place and belonging (Rees, 2019).

Locally Embedded Approaches to Design and Making

The success of Obregón and Bello's collaboration was rooted in their locally embedded approach, which was informed by place-based practices and local knowledge and materials. Both designers conducted research within their communities, focusing on the materials and techniques traditionally used to craft the 'Poporo' and the 'Mate' (Rees, 2019). This emphasis on local research and materiality was integral to the project, as it allowed the designers to ground their work in the specific cultural and environmental contexts from which these objects originated. Obregón and Bello's project also underscored the importance of local materials in design. For instance, they utilised the local *totumos* gourd, a natural material traditionally used in making the *Poporo* (usually in combination with gold), to craft their hybrid artefacts. Using locally sourced materials reinforced the objects' cultural significance and highlighted the environmental sustainability of working within local ecosystems.

Designing Across Distances: Online Collaborations

Obregón and Bello's project required the designers to collaborate online. Despite the remote collaboration, they managed to maintain a strong connection to their respective cultural and geographical contexts. Their ability to share the design process online while focusing on local research and materials demonstrated the potential of digital platforms to support collaborative innovation in a low-residency educational setting. This experience laid the groundwork for the consideration to develop a low-residency version of the MA Fashion Artefact course, illustrating how digital tools can facilitate cross-cultural dialogue and collaboration even when physical travel is restricted. By utilising online communication tools, designers in a low-residency course could continue their exploration of local identities and materials, proving that a locally embedded approach to design education can be sustained, even in a virtual environment.

Implications for Design Practices

Obregón and Bello's project represents a precedent that exemplifies the broader potential of material-led, place-based design practices to foster critical dialogue about cultural identity and sustainability. By focusing on working with locally sourced materials and traditional practices, they created artefacts which reflected their personal and cultural histories and contributed to preserving and revitalising traditional craftsmanship. Their work highlights the importance of integrating local knowledge and materials into design to foster a sense of place and identity. This approach aligns with the principles of locally embedded design education, emphasising the importance of working within the specific contexts of place and community to foster sustainable practices, if you gain a better understanding for your own heritage, culture and the materials around you that might allow for a more ethical and sustainable design (Gruenwald, 2003, my emphasis).

The collaboration between Daniel Ramos Obregón and Juliana García Bello is a compelling case study of how material-led design education can foster cross-cultural understanding and promote sustainable practices. Through their exploration of the *Poporo* and *Mate*, the designers could engage in a critical dialogue about cultural identity and regional craftsmanship, highlighting the importance of local materials and knowledge in design education. Their project also demonstrated the potential of digital platforms to support collaborative innovation in a low residency setting, paving the way for the development of new models of design education that are both locally embedded and globally connected (ahead of Covid).

Case Study 2: Design Across Geographies

These two case studies explore how the fundamental aspects of regional craftsmanship, which are deeply embedded in the original MA Fashion Artefact course, can be preserved and enhanced within a low-residency format. Central to this exploration is the symbiotic relationship between the creation process and its geographical context, particularly the significance of why an artefact is crafted in a manner consistent with its place of origin. The case study focuses on the academic year 2023-24, highlighting two students, Shiyu Gong and Ruolang Zeng, who exemplified the potential of place-based approaches by exploring their cultural heritage within the current model of the MA Fashion Artefact.

Shiyu Gong: Bamboo Craftsmanship and Heritage

Shiyu Gong's project serves as an example of how regional craftsmanship can be extended through innovation. Gong comes from a third-generation family business in bamboo crafts, a legacy embedded in his cultural heritage. During the Summer of 2023, during his postgraduate study, Gong undertook a two-week residency working closely with a local expert bamboo weaver, Hong-Guang Cai (See Figure 3); she leads a small studio, the only one that specialised in bamboo craft in Dongyang, a city well-known for woodcarving in China (China Design Center, 2019). This hands-on experience allowed him to better understand bamboo's properties, flexibility, and potential applications in contemporary design. Gong aimed for his project to merge this family tradition with leather moulding techniques, not merely an extension of his family's traditional craftsmanship but a reinvention. Gong produced artefacts that married old and new, local and global, integrating bamboo weaving techniques with leather craftsmanship (See Figure 2). His project underscores the value of place-based design education in fostering innovation while maintaining strong ties to cultural roots. The ability to work with local artisans and access regionally specific materials was fundamental to his creative process. By staying connected to the geographical origins of bamboo craftsmanship, Gong could innovate in a way that was respectful of tradition and forward-thinking. This fusion of regional craftsmanship with modern design practices exemplifies the potential of place-based education to preserve cultural heritage while contributing to the evolution of traditional crafts.

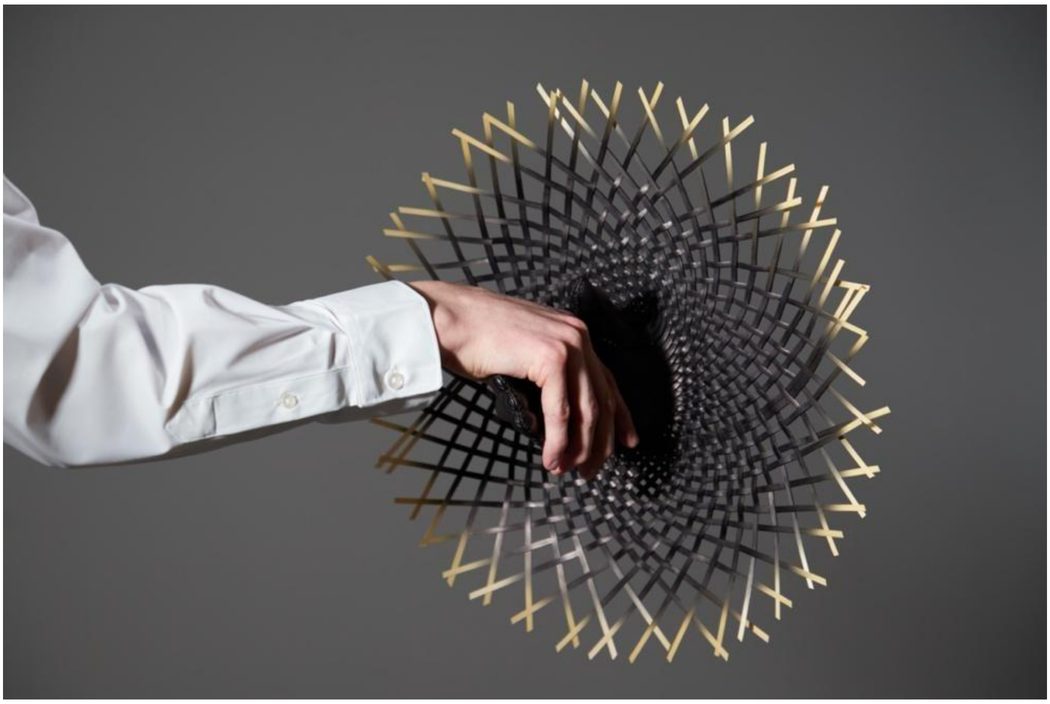

Fig 2. Shiyu Gong (2024) Photography for the Masters project portfolio

Fig 3. Shiyu Gong (2024) Photo of the residency studio in Dongyang

Ruolang Zeng: Jade and Lacquer work

Ruolang Zeng's project centres on the jade seal, a material artefact imbued with profound symbolic and cultural significance in Chinese history. Zeng's engagement with this material was deeply personal, as she sought to explore contemporary power dynamics while reflecting on the broader cultural meanings associated with jade. In executing her project, Zeng researched traditional jade carving techniques but replaced them with the ancient Chinese lacquerware method (see Figure 3). This material-driven approach enabled her to craft a series of artefacts that emulate the appearance of jade through the technique of wiping lacquer ("擦漆"). This process involves applying lacquer to the surface of wood and wiping it off before it fully dries, leaving a thin layer that is repeatedly applied until the desired thickness is achieved, followed by polishing. The technique imparts a gentle gloss to the wooden surfaces, akin to jade's lustrous finish. Zeng's work engages with jade's rich cultural history while also exploring novel ways of representing power relations through materiality. By transforming the Jade Seal—traditionally used to mark documents with a signature—into a performative and artistic artefact that interacts with the body, Zeng suggests a new interpretation of power between individuals. This project exemplifies how place-based education can foster a connection to cultural heritage, while simultaneously encouraging innovation and the expansion of traditional practices.

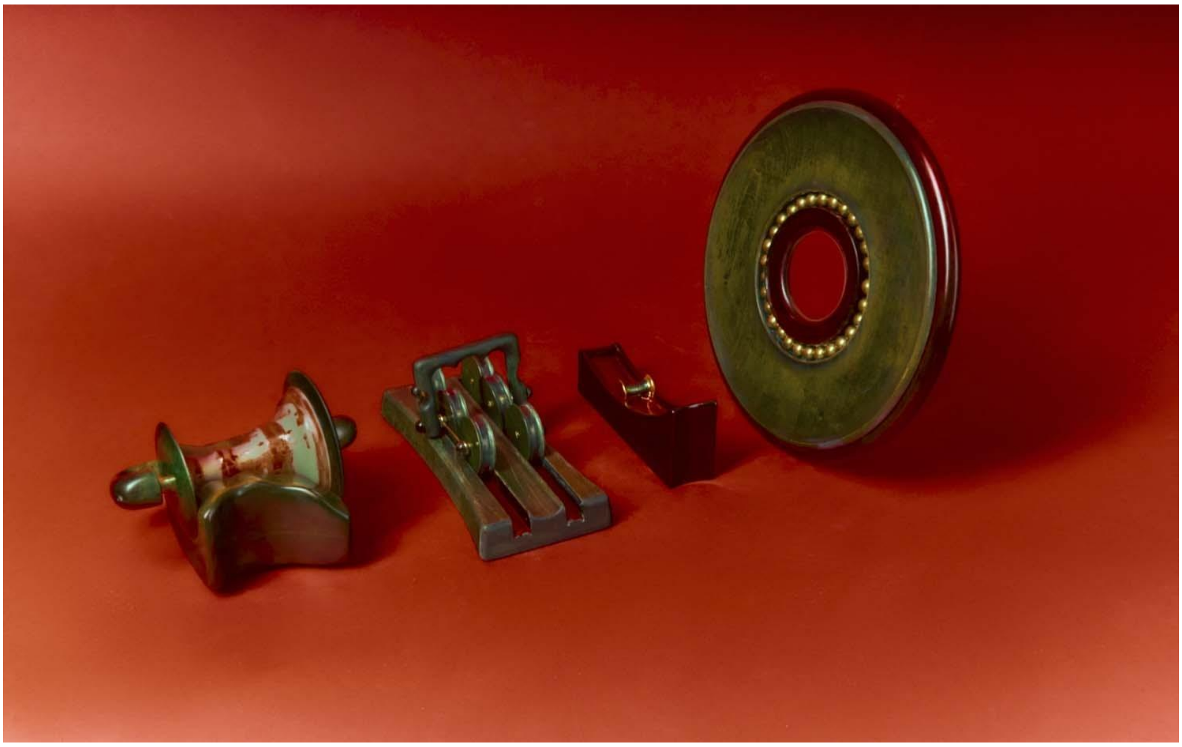

Fig 4. Ruolang Zeng (2024) photography of the final collection of artefacts for the Masters project

Reflections

To be clear, it is crucial to point out that these two student projects were not completed within a low-residency programme, instead in an in-person setting. However, by engaging deeply with geographically bound materials and expertise, they are relevant case studies that can help us understand how local collaborations are beneficial. Their projects exemplify how place-based education can allow students to not only develop their technical skills but also deepen connections to their cultural heritage. During their projects, both students ordered materials from their home countries to be delivered to the United Kingdom, which negatively impacted upon their carbon footprint, a problem that would be mitigated by a low-residency approach. By working with local materials and learning regionally specific techniques, the students were encouraged to consider the ecological impact of their work. This form of education fosters environmental stewardship by emphasising the importance of sustainable practices that are rooted in the local context. If students are not in a low residency setting, however, some of these connections may be weakened, as students cannot always engage as deeply with the local context. Gong and Zeng's projects highlight the potential of place-based, material-led design education to bridge the gap between tradition and innovation. I believe that both projects would have benefitted from more locally embedded design approaches that kept them in closer contact with local artisans and communities, which could be developed within a low residency and place-based programme. Such an approach would allow students to remain connected to their work's geographical and cultural origins, perpetuating craftsmanship traditions while considering local ecologies and the sustainability of their practices.

Discussion

This paper argues that material-led low residency study represents a promising potential paradigm for future ecological, social, and economic dimensions, an education model that has the potential to transform design education and foster global collaboration. The presented case studies illustrate the potential of place-based education to preserve and revitalise traditional craft while fostering innovation. Through the analysed projects, it becomes evident that regional craftsmanship and material-led approaches are essential to maintaining cultural heritage in a contemporary design context. These examples also highlight the importance of geographical context in the design process and the potential challenges posed by low-residency settings in maintaining strong connections to place. Ultimately, this investigation underscores the value of place-based, geographically embedded design education in crafting a sustainable future for traditional crafts.

One of the key contributions of this approach is its emphasis on material literacy, which enables students to make informed decisions about material choices and advocate for sustainable practices in their careers. This knowledge is crucial for addressing the systemic challenges of resource depletion and environmental degradation, particularly in fashion-related industries. Moreover, incorporating local materials and ILEK into the curriculum provides students with a context-specific understanding of sustainability. This approach would reduce the environmental impact of long-distance material transport and foster a deeper appreciation for local ecosystems and cultural heritage. By engaging with place-based approaches and regional resources, students could more easily develop innovative solutions to complex sustainability challenges rooted in their own cultural and ecological contexts. The case studies presented in this paper highlight the potential of material-led design education to foster cross-cultural understanding and collaboration. By engaging with their own cultural heritage and local materials, students can explore the connections between material culture and identity, leading to a deeper understanding of the role of design in shaping cultural narratives. Furthermore, this approach promotes a more equitable and resilient future by empowering students to engage with their communities and contribute to local economies. Material-led low residency programs could help preserve traditional knowledge while promoting sustainable practices deeply embedded in local contexts by fostering collaboration between academic institutions and regional artisans.

In conclusion, this paper has explored how material-led low residency education can offer a robust framework for sustainable educational practices deeply rooted in place-based approaches, regional craftsmanship, and cultural heritage. By integrating theoretical insights with practical examples, this research underscores the transformative potential of a pedagogy that imparts material literacy and fosters a meaningful engagement with the local contexts in which students are embedded. The findings suggest that design education can move towards a more sustainable and equitable future by embracing material-led, place-based approaches. This approach not only equips students with the skills and knowledge they need to succeed in their careers but also instils in them a sense of responsibility towards their communities and the global environment. As educational institutions grapple with the challenges of the Anthropocene, these models offer a promising pathway forward.

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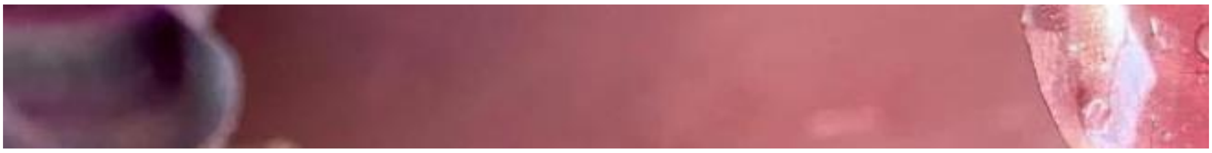

Exploring the Allure of Mud-Dye: An Interview with Artisan JianPing Xiang on Sustainable Practices

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Keywords: Mud- Dyeing; Process characteristics; post-mordant materials; Biomaterials; Sustainable Practice; Circular Economy; Cultural Heritage; Community Empowerment.

Introduction

The global textile industry is under increasing pressure to adopt sustainable practices due to its significant environmental impact, with consumer demand and regulations advocating for reduced water usage, chemical waste, and emissions. To address these challenges, frameworks such as the circular economy, cradle-to-cradle principles, and bio-based production methods are gaining traction for their resource efficiency. Traditional techniques, such as mud-dyeing, offer a compelling alternative to resource-intensive modern practices by utilizing natural, locally sourced materials and incorporating closed-loop systems. This study addresses a gap in sustainable textile practices by examining how traditional mud-dyeing, as practiced by JianPing Xiang, can promote environmental sustainability and empower communities. While contemporary approaches often prioritize industrial solutions, this research underscores the advantages of a culturally embedded, craft-based approach to sustainability, highlighting low-impact methods, biodegradable materials, and community resilience. Xiang's mud-dyeing techniques exemplify how heritage crafts can integrate principles of resource conservation and socio-economic empowerment, bridging traditional knowledge with modern sustainability needs. Additionally, this study builds on research by Fletcher (2014), Clark (2008), and the Ellen MacArthur Foundation (2017), which advocate for sustainable, slow fashion and bio-based production. However, while these frameworks emphasize low-impact design, they often overlook traditional, craft-based practices. By positioning mud-dyeing as a viable and scalable model, this study emphasizes its ecological, economic, and cultural advantages, promoting more sustainable and culturally mindful practices within the textile industry. Fig 1 and Fig 2 present the theoretical models of circular economy, cradle-to-cradle.

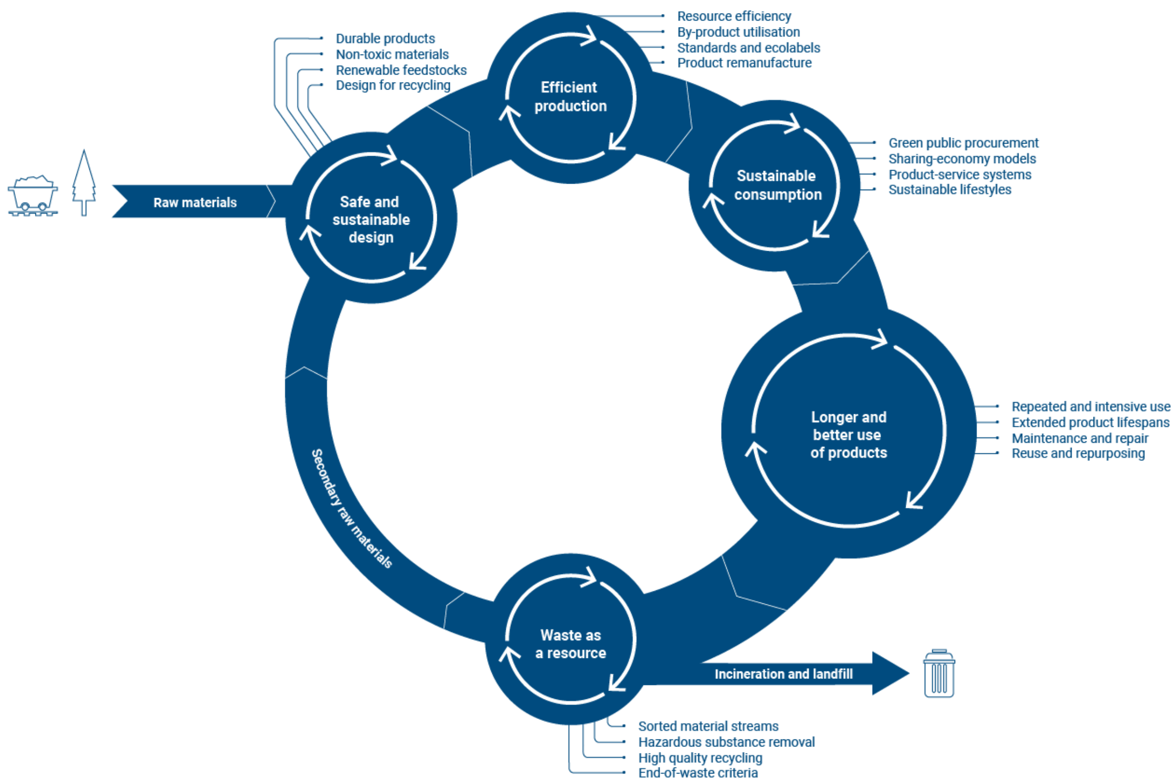

Fig 1. EEA (2024) The circular economy concept.
Source: https://www.eea.europa.eu/publications/capturing-the-climate-change-mitigation

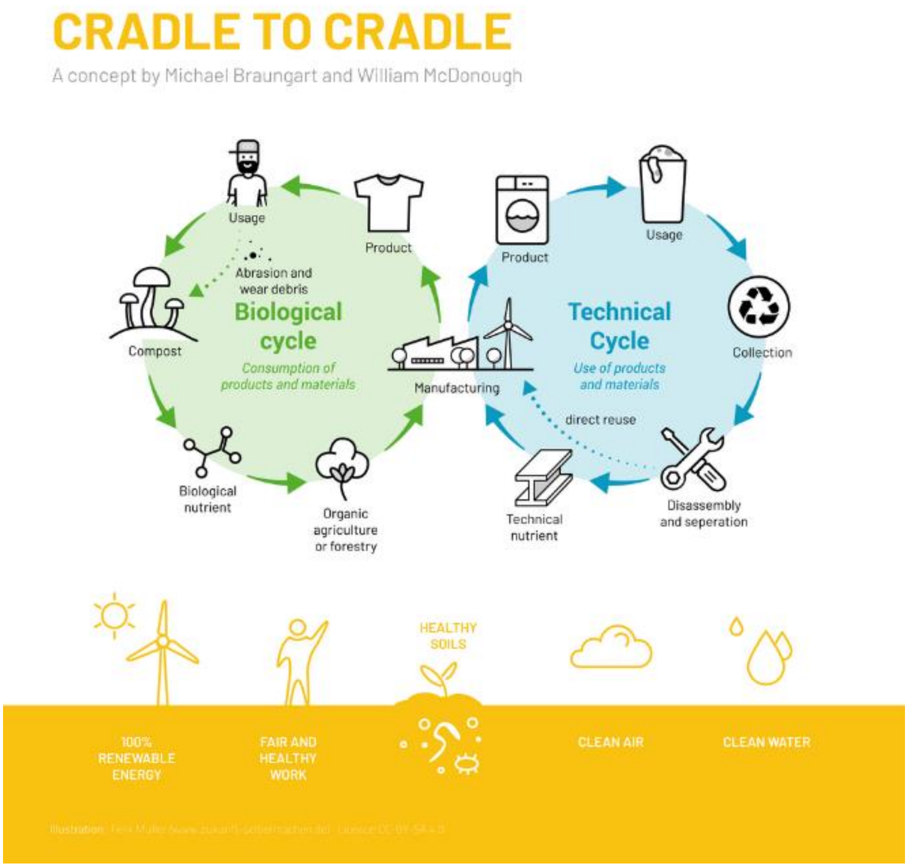

Fig 2. Wikipedia (2024) Framework of Cradle-to-Cradle Design
Source: https://en.wikipedia.org/wiki/Cradle-to-cradle_design

Mud-Dyeing as a Sustainable Practice – Insights from JianPing Xiang

Overview of the Mud-Dye Process

JianPing Xiang's mud-dyeing process is deeply rooted in traditional methods passed down through generations in rural Hunan. As a dedicated artisan, Xiang has not only preserved these methods but also refined and adapted them to meet contemporary sustainability standards. To gather insights into Xiang's techniques, this study employed a combination of interviews, fieldwork, and collaborative workshops to closely document her process. By observing Xiang in her natural environment and engaging in hands-on dyeing activities, the study captured both the technical intricacies and the cultural depth of her craft. Xiang explained that her mud-dyeing process begins with the careful selection of natural materials, such as plant leaves and local soil, which form the foundation of the dye (Xiang, 2024). These materials are boiled to extract natural pigments, and the dye mixture is crafted by blending plant compounds with the unique mineral composition of the local mud. This non-corrosive and non-toxic approach ensure minimal environmental impact, contrasting sharply with industrial chemical dyes known for causing significant soil and water pollution.

One methodological challenge in this research was capturing the full depth of Xiang's closed-loop recycling process, where each batch of mud is reused, enhancing the bio-properties of the materials over time. To address this, multiple site visits and follow-up interviews were conducted to track how the mud's properties evolved with each reuse, thereby adding reliability to the observations. After dyeing, fabrics are immersed in the mud for several hours to absorb pigments fully, followed by thorough washing and drying. Xiang's commitment to ecological conservation through local materials and traditional knowledge illustrates the viability of mud-dyeing as a sustainable alternative to industrial dyeing processes, reinforcing its relevance in modern sustainable design. Reflecting on the limitations, the study encountered challenges in documenting all variables within Xiang's natural and seasonal cycles, such as variations in mud properties due to weather changes. These factors, while difficult to control, add authenticity to the findings and emphasize the importance of localized environmental factors in sustainable craft practices. This investigation into Xiang's mud-dyeing methods underscores how traditional crafts can be reimagined to align with global sustainability goals, preserving both environmental health and cultural heritage (Xiang, 2024). Fig 3 displays the basic progress of mud-dyeing in Xiang's studio.

Fig 3. Yan Feng (no date) Mud-dyeing Process Flowchart

Sustainability Principles in Mud-Dyeing

Based on insights gathered through interviews, fieldwork, and collaborative workshops with JianPing Xiang (Xiang, 2024), this study explores her approach to mud-dyeing, which emphasizes sustainability through eco-friendly techniques rooted in traditional craftsmanship. To capture the nuances of Xiang's methods, interviews were conducted to understand her philosophical approach to sustainable practices, while field observations and collaborative workshops provided a closer examination of her dyeing process in action. By actively participating in the workshops, the study documented firsthand the steps and techniques used by Xiang, capturing both practical applications and cultural context. Xiang highlights the importance of selecting natural materials, such as plant leaves and local soil, which are carefully boiled to extract pigments that form the foundation of her dye. By utilizing locally sourced resources, she avoids harmful synthetic chemicals, promoting a non-toxic, non-corrosive process that minimizes environmental impact. A key aspect of her practice is the closed-loop recycling of the mud used in the dyeing process; rather than depleting resources, she continuously reuses the same mud, enhancing its bio-properties over time. This reflects her commitment to sustainable land and resource management.

Documenting the intricacies of Xiang's closed-loop recycling process posed a methodological challenge, as the properties of the mud and pigments evolve subtly over multiple uses. To address this, follow-up interviews and repeat field visits were conducted to observe gradual changes and validate findings, thereby enhancing the reliability of the data.

Xiang further explains how fabrics absorb the natural pigments after soaking in the mud for several hours, followed by washing and drying—a traditional technique that produces vibrant, durable textiles without the environmental harm associated with industrial dyeing processes. Xiang's philosophy canters on maintaining ecological balance, respecting natural resources, and preserving the integrity of her craft. Her dedication to sustainable practices not only aligns with global sustainability goals, such as responsible consumption and production (SDG 12), but also ensures her methods remain relevant to today's environmental challenges. Reflecting on limitations, this study encountered seasonal and environmental variations, such as changes in mud composition due to weather conditions. These variables, while difficult to control, add authenticity to the findings and underscore the importance of environmental adaptation in sustainable craft practices. Xiang's work fosters a meaningful connection between traditional knowledge and modern sustainability, illustrating how ancient practices can adapt to contemporary needs while preserving cultural heritage (Xiang, 2024).

Xiang's Vision of Sustainability

JianPing Xiang's vision of sustainability is deeply influenced by her personal experiences and long-standing commitment to eco-friendly practices in the traditional craft of mud-dyeing. For Xiang, sustainability is not merely a trend but an essential part of her philosophy, rooted in respect for natural resources and a commitment to minimizing environmental harm. In her interview, Xiang emphasizes the importance of using non-toxic, non-corrosive materials in her dyeing process, which contrasts sharply with the environmental damage often caused by industrial dyeing methods. Her approach prioritizes a closed-loop system, closely aligned with circular economy principles, where resources like mud are continuously recycled to enhance their bio-properties and promote long-term sustainability (Xiang, 2024). Xiang's methods also embody bio-based production by relying on renewable, locally sourced organic materials. This alignment with global sustainability trends demonstrates how traditional craft methods, such as mud-dyeing, can serve as viable, low-impact alternatives to synthetic, resource-intensive practices. By using materials like plant leaves and local soil, Xiang's mud-dyeing offers a model that reduces reliance on synthetic chemicals and supports regional economies, addressing the global call for sustainable textile manufacturing practices that reduce carbon emissions and environmental harm.

Additionally, Xiang highlights the critical role of traditional knowledge in promoting ecological balance. By adhering to time-honoured methods and sourcing materials locally, she aims to preserve the environment while maintaining the cultural heritage of mud-dyeing. Her practices not only minimize waste but also ensure that land and resources are used sustainably, making her approach a practical solution to current environmental challenges in the textile industry. The focus on recycling and bio-based materials offers a practical, scalable model that contrasts with the wasteful and environmentally harmful practices of industrial textile dyeing. For Xiang, sustainability encompasses more than environmental aspects—it includes social responsibility as well. Her work provides economic support to local artisans, particularly women, fostering community growth alongside environmental stewardship. This holistic view of sustainability, integrating environmental, social, and cultural dimensions, reflects Xiang’s dedication to a practice that honours the past while addressing the pressing ecological challenges of the present. Her approach illustrates how traditional crafts can fit into, and even challenge, modern sustainability movements, such as the circular economy and bio-based production, by offering practical, low-impact alternatives that are adaptable and rooted in cultural heritage (Xiang, 2024).

Environmental Engineering and Resource Management in Mud-Dyeing

Land and Resource Management Techniques

JianPing Xiang's approach to environmental engineering and resource management in mud-dyeing reflects a profound commitment to sustainability. Through interviews, fieldwork, and collaborative workshops with Xiang (Xiang, 2024), this study explored the intricacies of her methods. These interactions provided a firsthand look into her carefully crafted resource management techniques, which ensure that the dyeing process remains both eco-friendly and efficient. A key feature of her approach is the closed-loop system embedded in her dyeing process, where natural materials, such as plant leaves and mud, are continuously recycled. Rather than discarding the mud after each use, Xiang reintegrates it into the fields to support crop growth, including rice. This practice not only prevents resource depletion but also enriches the soil, replenishing essential elements such as iron through the natural decomposition of plant roots (Xiang, 2024). Documenting these cyclical processes presented methodological challenges, particularly in tracking the nutrient effects on the soil over time. Multiple site visits and repeated observations were conducted to monitor the soil's gradual enrichment, strengthening the study’s reliability. Xiang also emphasizes the critical role of water as a resource in her system. The water used in dyeing is collected in a pond, where natural filtration and sedimentation processes allow for repeated reuse, eliminating the need for chemical treatments. This approach conserves water, reduces waste, and further minimizes the environmental impact of her mud-dyeing practice (Xiang, 2024).

By integrating these sustainable land and resource management techniques, Xiang has created a self-sustaining, ecologically balanced system that aligns with her vision of minimal environmental impact. Her methods not only preserve local natural resources but also serve as a model for sustainable craft practices that can be applied more broadly, merging traditional knowledge with modern ecological principles. Challenges encountered in documenting Xiang’s closed-loop techniques, such as seasonal variations in water quality and mud composition, were addressed through consistent observation and adaptive data collection methods, which added depth to the study's findings. Xiang’s practices offer a valuable blueprint for sustainable development in traditional crafts and demonstrate the potential of artisanal methods in promoting ecological balance (Xiang, 2024).Fig shows how Xiang’s closed loop system concepts reflect in her studio.

Fig 4. Yan Feng (no date) Schematic of Xiang's Studio's closed loop system.

Environmental Benefits of Mud-Dye

Xiang highlights the numerous environmental benefits of the mud-dyeing process, emphasizing its alignment with eco-friendly practices and sustainability principles. A key advantage of mud-dyeing lies in its reliance on natural materials and the closed-loop system that Xiang has established. Unlike synthetic dyes, which often contribute significantly to environmental degradation, mud-dyeing utilizes locally sourced resources such as plant leaves and soil, recycling these elements continuously to minimize waste. In alignment with circular economy principles, the mud used in the dyeing process is not discarded; instead, it is returned to the fields, enriching the soil with essential minerals like iron and supporting agricultural growth, thus preserving the ecological balance of the land (Xiang, 2024). In addition to soil enhancement, water management is central to Xiang's sustainable practices. The water used in the dyeing process is filtered and reused, reducing the overall consumption of fresh water. This approach not only minimizes environmental impact but also conserves vital water resources, particularly in regions facing water scarcity. Xiang's method of filtering and reusing water reflects a commitment to resource efficiency, a cornerstone of both circular economy and bio-based production models. By integrating these principles, her mud-dyeing process offers a sustainable alternative to resource-intensive industrial dyeing, which often contributes to environmental pollution and waste.

Xiang views mud-dyeing as a harmonious interaction between nature and craft, allowing artisans to create textiles while preserving the environment's integrity. Through her focus on locally sourced, renewable materials, Xiang's practices embody bio-based production principles by reducing reliance on synthetic chemicals and minimizing carbon emissions associated with transporting raw materials. This locally adapted, low-impact model addresses some of the most pressing environmental challenges in textile manufacturing today, offering a practical solution for sustainable textile production that supports both regional economies and ecological health. By implementing these environmentally conscious methods, Xiang demonstrates how traditional craft techniques can contribute to broader sustainability efforts. Her practices showcase the potential for eco-friendly alternatives to industrial processes, reducing environmental harm while preserving cultural heritage and fostering sustainable development within local communities. Xiang's work not only exemplifies the integration of traditional knowledge with modern sustainability movements but also challenges the textile industry to consider scalable, sustainable practices grounded in ecological and cultural responsibility (Xiang, 2024).

Alignment with Broader Sustainability Movements

JianPing Xiang's environmental strategies, as shared during her interview, align closely with global sustainability goals, particularly those focused on resource conservation, ecological balance, and community well-being. Her closed-loop system in mud-dyeing, where materials such as mud and plant-based elements are recycled and reused, exemplifies her commitment to SDG[6] 12 (Responsible Consumption and Production). By continuously recycling the mud used in the dyeing process, Xiang minimizes waste and enhances soil fertility, supporting sustainable agriculture in the region and aligning with circular economy principles that prioritize resource efficiency and the continuous use of materials (Xiang, 2024).

Additionally, Xiang's water management techniques—where water used in dyeing is filtered and reused—address broader concerns about water scarcity, aligning with SDG 6 (Clean Water and Sanitation). She emphasizes that water is a precious resource, especially in regions with limited access, and her efficient use of water reflects a commitment to sustainable freshwater management. This approach not only conserves water but also demonstrates how traditional craft practices can be adapted to address modern water scarcity concerns, offering practical applications for resource management in textile production (Xiang, 2024). Xiang's practices also contribute to SDG 13 (Climate Action) by reducing the carbon footprint commonly associated with industrial dyeing. Through her use of locally sourced materials like plant leaves and minerals from mud, she avoids emissions linked to the transportation and production of synthetic dyes and chemicals, illustrating a bio-based production model that relies on renewable, biodegradable materials. This approach not only lowers emissions but also supports local economies by sourcing materials regionally, reinforcing the socio-economic sustainability central to bio-based production. Furthermore, Xiang's practices contribute to SDG 15 (Life on Land) by protecting ecosystems from pollutants. By utilizing natural, non-toxic materials and maintaining environmental harmony, she helps sustain biodiversity and promote long-term ecological health. Her emphasis on ecological balance demonstrates how natural dyes, rooted in traditional techniques, can provide sustainable, low-impact alternatives that challenge the harmful environmental practices of conventional textile manufacturing (Xiang, 2024).

Through these efforts, Xiang illustrates how traditional craftsmanship can be reimagined to align with, and even challenge, modern sustainability movements such as the circular economy and bio-based production. Her approach to mud-dyeing offers a scalable, low-impact model

[6] Sustainable Development Goals (SDGs)
The Sustainable Development Goals (SDGs) are a set of 17 global goals established by the United Nations in 2015 as part of the 2030 Agenda for Sustainable Development. These goals aim to address urgent global challenges, including poverty, inequality, climate change, environmental degradation, peace, and justice. The SDGs are intended to guide countries and organizations worldwide toward achieving a sustainable future for all, with specific targets and indicators for progress.

for the textile industry that integrates ecological conservation with cultural heritage. By addressing key environmental challenges in textile manufacturing, her methods provide a blueprint for sustainable production that prioritizes resource efficiency, reduces carbon emissions, and supports biodiversity, showcasing the potential of traditional crafts to meet contemporary sustainability goals (Xiang, 2024).

The Circular Economy and Bio-Based Production

The circular economy model, which prioritizes the continuous use of resources through recycling, reuse, and waste minimization, is increasingly recognized as a foundational framework for sustainable development (Ellen MacArthur Foundation, 2017). This model aims to extend product lifecycles, reduce resource extraction, and minimize environmental impact by creating closed-loop systems where materials are continuously repurposed. To examine how these principles apply in traditional craft contexts, this study utilized interviews, fieldwork, and collaborative workshops with mud-dyeing artisan JianPing Xiang. These methods provided insight into her sustainable techniques and how they align with circular economy principles, particularly in her approach to recycling natural materials like mud and plant-based dyes.

Instead of discarding materials after each dyeing cycle, Xiang reintegrates the enriched mud back into agricultural fields, where it aids soil regeneration and supports crop growth. This not only reduces waste but also enhances soil health, illustrating how circular practices can effectively be integrated into traditional craft settings. A challenge in capturing the effects of these practices on soil regeneration over time was addressed by conducting multiple site visits and gathering observational data on crop growth and soil quality, which strengthened the study's reliability. In addition to circular economy principles, the concept of bio-based production—using renewable, organic materials for manufacturing—has gained traction as a way to reduce reliance on synthetic chemicals and petroleum-based products (Kumar and Yadav, 2020). Bio-based production reduces carbon emissions and promotes locally sourced, biodegradable resources. Xiang's use of natural materials, such as plant leaves and local soil, in her mud-dyeing exemplifies this approach. Her reliance on locally available organic compounds aligns with global efforts to reduce transportation emissions and support regional economies, making her practice both environmentally friendly and socio-economically sustainable. Xiang's methods also contribute to broader sustainability goals, such as those outlined in the United Nations Sustainable Development Goals (SDGs), particularly SDG 12 (Responsible Consumption and Production) and SDG 13 (Climate Action). Her commitment to using non-toxic materials and minimizing water waste reflects a shift towards responsible production processes that emphasize environmental stewardship. Documenting Xiang's process posed challenges due to seasonal and environmental factors, such as variations in the availability and quality of raw materials. These challenges were mitigated through adaptive data collection and seasonal observations, adding depth and reliability to the findings.

By integrating these broader sustainability concepts into her work, Xiang demonstrates how traditional craft methods can effectively address contemporary environmental challenges, bridging the gap between ancient knowledge and modern sustainability. Her practices offer a practical, locally adapted model that aligns with the principles of the circular economy and bio-based production, serving as a valuable example in the global pursuit of sustainable development (Ellen MacArthur Foundation, 2017; Kumar and Yadav, 2020).

Cultural and Socio-Economic Impact of Mud-Dye

Cultural Significance of Mud-Dye in Hunan Province

The cultural significance of mud-dyeing in Hunan is deeply embedded in local traditions and personal identity, as highlighted by JianPing Xiang in her interview with interviewer Yan Feng, the author herself. For Xiang, mud-dyeing represents far more than a craft; it is a symbol of cultural continuity passed down through generations in the rural communities of Hunan. This ancient technique, which relies on natural materials like mud and plant leaves, serves not only as a practical dyeing method but also as a vessel for preserving the values and wisdom of her ancestors, reflecting the rich cultural heritage of the region (Xiang, 2024).

Xiang's dedication to preserving this traditional craft demonstrates her strong personal connection to mud-dyeing. For her, it is a way to honour her forebears and ensure that their knowledge continues to thrive in a modern context. By practicing and teaching these methods, she sustains a legacy that is deeply woven into the local way of life. Her community, in this context, refers to the village where Xiang lives—a close-knit network of residents who share a common cultural heritage and a collective pride in this unique craft**.** The community takes immense pride in mud-dyeing, and Xiang's efforts to pass it on to younger generations help ensure its survival despite the pressures of industrialization and modern dyeing techniques (Xiang, 2024). Beyond cultural preservation, Xiang's approach to mud-dyeing aligns closely with global sustainability concepts like the circular economy and bio-based production. By using a closed-loop system where materials like mud are recycled and reused, Xiang minimizes waste and supports ecological balance. This method echoes the principles of the circular economy, offering a model for resource efficiency that contrasts with the wasteful practices of industrial textile production. Her use of plant-based dyes, drawn from renewable, local sources, further embodies bio-based production principles, creating an eco-friendly alternative that reduces dependency on synthetic chemicals and supports local ecosystems. Xiang also emphasizes the socio-economic significance of mud-dyeing within her community, particularly in empowering local artisans, many of whom are women. Through mud-dyeing, these artisans not only maintain their cultural identity but also contribute to the economic vitality of their region. Xiang's work has created opportunities for women to achieve financial independence while preserving both the environment and their cultural heritage. This model of sustainable production exemplifies how cultural practices can evolve to address modern socio-economic needs while maintaining ecological balance, offering practical solutions to current environmental challenges in textile manufacturing (Xiang, 2024).

As she explains, mud-dyeing represents a harmonious blend of tradition, community, and sustainability, bridging the gap between cultural heritage and environmental stewardship. Xiang's practices not only provide a path for sustainable textile production but also challenge the industry to consider traditional methods as viable, low-impact solutions that prioritize both cultural and ecological sustainability (Xiang, 2024). Fig 4 demonstrates the daily work of these female artisans who work in Xiang's mud-dyeing studio.

Fig 4. Yan Feng (no date) Female artisans were working in Xiang's mud-dyeing studio.

Economic Benefits for Local Artisans

Xiang's work in mud-dyeing has had a profound economic impact on local artisans, particularly women, who make up most of the workforce in her community. She emphasizes that mud-dyeing is not merely a craft but a crucial economic resource for rural areas in Hunan (Xiang, 2024). By offering employment opportunities to local women—many of whom have limited access to jobs outside their homes—her workshop provides a stable income while allowing these artisans the flexibility to balance work with household responsibilities. Many women in Xiang's workshop are elderly or primary caregivers, and the flexible working hours enable them to contribute economically without compromising their ability to manage family duties (Xiang, 2024).

Xiang's approach aligns with broader research on the empowerment of women through craft, echoing studies that highlight how traditional crafts can foster financial independence and community resilience among women in rural communities (UNESCO, 2013). Like craft-based economic models in other regions, such as the kantha stitching communities in India or basket-weaving collectives in Kenya, mud-dyeing offers these women a sense of agency and a renewed sense of purpose and pride in their work. By preserving traditional craftsmanship while promoting economic self-sufficiency, Xiang's workshop exemplifies how craft practices can support not only financial gain but also personal empowerment and social inclusion. Through her workshop, Xiang has cultivated a community-driven approach to sustainability, where local resources are managed carefully, and artisans are both valued and supported. This model of empowerment through sustainable craft production could be replicated in other underdeveloped regions, where the integration of traditional skills with sustainable economic practices can foster economic resilience. The model provides a blueprint for how communities with limited industrial infrastructure can build economic independence through culturally rooted, environmentally friendly crafts that respect local ecosystems and heritage.

Moreover, Xiang's mud-dyeing workshop has contributed significantly to the broader socio-economic landscape by maintaining strong connections with both local and international markets. Although her workshop remains relatively small, its focus on high-quality, eco-friendly products has attracted a loyal clientele, both domestically and internationally. The growing demand for sustainable textiles underscores the potential of mud-dyeing to drive local economic development while promoting environmentally responsible practices. If adopted in other regions, this model could support economic resilience in rural areas, providing sustainable livelihoods and preserving cultural heritage while meeting global demand for ethical and sustainable products (Xiang, 2024).

Empowerment and Gender Equality

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Xiang's approach aligns with broader research on the empowerment of women through craft, resonating with studies that show how traditional crafts can foster financial independence and community resilience among women in rural communities (UNESCO, 2013). Similar to other craft-based economic models, such as kantha stitching collectives in India or basket-weaving groups in Kenya, mud-dyeing offers these women a sense of agency, independence, and pride in their work. These craft-based economic models have consistently shown that when women engage in culturally rooted, community-supported crafts, they not only gain financial stability but also experience greater social inclusion and empowerment. By preserving traditional craftsmanship while promoting economic self-sufficiency, Xiang's workshop exemplifies how craft practices can support not only financial gain but also personal empowerment and community cohesion. Her model highlights the potential for traditional crafts to contribute to social equity by providing income and opportunity in communities where industrial employment options may be scarce. Through her workshop, Xiang has cultivated a community-driven approach to sustainability, where local resources are carefully managed, and artisans are both valued and supported. This empowerment model could be replicated in other underdeveloped regions, where the integration of traditional skills with sustainable economic practices can foster economic resilience. Xiang's model serves as a blueprint for how communities with limited industrial infrastructure can build economic independence through culturally rooted, environmentally friendly crafts that respect local ecosystems and heritage. The replication of such models in other regions has the potential to create sustainable, community-led economic growth while preserving valuable cultural practices.

Moreover, Xiang's mud-dyeing workshop has contributed significantly to the broader socio-economic landscape by maintaining strong connections with both local and international markets. Although her workshop remains relatively small, its focus on high-quality, eco-friendly products has attracted a loyal clientele, both domestically and internationally. The growing demand for sustainable textiles underscores the importance of mud-dyeing in local economic development, enabling artisans to thrive while promoting environmentally responsible practices. If adopted in other regions, this model could support economic resilience in rural areas, providing sustainable livelihoods and preserving cultural heritage while meeting global demand for ethical and sustainable products (Xiang, 2024).

Cultural Preservation in the Global Market

Xiang's perspective on cultural preservation in mud-dyeing canters on balancing the maintenance of traditional methods with the pursuit of economic growth. She emphasizes the importance of upholding the integrity of mud-dyeing techniques passed down through generations in Hunan, viewing them as a crucial link to the region's cultural heritage (Xiang, 2024). These traditional methods, which use locally sourced natural materials like mud and plant leaves, hold value not only for their environmental benefits but also for preserving the stories and wisdom of her ancestors (Xiang, 2024).

Xiang firmly believes that economic development and cultural preservation are not mutually exclusive. Instead, she sees the potential for traditional crafts like mud-dyeing to thrive within the modern economy, as long as their core values and techniques are respected (Xiang, 2024). Through her workshop, Xiang strives to maintain the authenticity of the craft while adapting it to contemporary market demands. This approach allows her to create economic opportunities for local artisans while ensuring that the cultural essence of mud-dyeing remains intact, providing artisans with both a livelihood and a source of cultural pride. This model aligns with broader frameworks seen in other craft-based communities, such as the embroidery cooperatives in Oaxaca, Mexico, and pottery collectives in Morocco, where artisans have successfully adapted traditional practices for modern markets while preserving their cultural significance. Studies show that when traditional crafts are valued within contemporary economies, they contribute not only to economic growth but also to social cohesion and community resilience (UNESCO, 2013). Like these communities, Xiang's approach illustrates how traditional knowledge and cultural identity can be preserved, even as craft practices adapt to meet market demands. Xiang acknowledges the challenge of balancing these two aspects, particularly amid the pressures of industrialization and mass production (Xiang, 2024). She stresses the importance of remaining true to traditional methods, even as the demand for eco-friendly textiles grows in both domestic and international markets. According to Xiang, preserving the traditional process not only sustains cultural identity but also adds value to the products, offering customers a deeper connection to the heritage embedded in each piece of fabric (Xiang, 2024). In her view, mud-dyeing represents a harmonious blend of cultural preservation and economic growth, demonstrating how traditional knowledge can adapt to meet the needs of a changing world without losing its roots.

Xiang's model also holds the potential for replication in other regions and cultures, particularly in underdeveloped areas where economic resilience is essential. By integrating traditional skills with sustainable economic practices, communities can foster economic independence while preserving cultural heritage. This approach provides a blueprint for how culturally rooted; environmentally friendly crafts can build economic resilience in regions with limited industrial infrastructure. If adopted in other regions, Xiang's model could contribute to sustainable, community-led economic growth, helping similar communities preserve their cultural heritage while connecting to global markets with demand for ethical, sustainable products.

Broader Implications for Sustainable Design and the Future of Mud-Dye

Mud-Dyeing as a Model for Sustainable Craft Practices

Mud-dyeing serves as a prime example of a sustainable craft practice, offering valuable insights into broader applications for sustainable design within the textile industry. Rooted in traditional knowledge, mud-dyeing aligns closely with contemporary sustainability models, such as the circular economy and bio-based production. This practice emphasizes the use of locally sourced, natural materials like plant leaves and soil, which are essential for creating a low impact dyeing process. By reducing reliance on synthetic chemicals, mud-dyeing minimizes environmental pollution and promotes ecological balance, demonstrating the potential for biodegradable and renewable materials in sustainable production (Kumar and Yadav, 2020).

A key strength of mud-dyeing is its emphasis on closed-loop systems. By recycling materials such as mud and water used in the dyeing process, mud-dyeing aligns with the circular economy's focus on resource efficiency and waste minimization (Ellen MacArthur Foundation, 2017). The practice of returning used mud to agricultural fields, where it supports soil health and crop growth, illustrates how waste can be repurposed as a resource. This closed-loop approach not only minimizes waste but also contributes to soil regeneration, offering a sustainable model that could inspire innovation across other areas of the textile industry. By merging traditional wisdom with modern sustainability goals, mud-dyeing provides a practical blueprint for resource conservation and reducing environmental impact, illustrating how traditional practices can lead the way in sustainable textile production (Xiang, 2024). Moreover, mud-dyeing's reliance on local resources highlights the importance of community-based production models in promoting sustainable practices. This approach supports regional economies and reduces the carbon footprint associated with long-distance transportation of materials, aligning with bio-based production principles. It reflects the growing emphasis on localized production and consumption in sustainable fashion, where the ecological footprint is minimized using region-specific resources (Fletcher, 2014). The practice encourages artisans to maintain a strong connection to their environment, fostering an appreciation for the ecological systems that sustain their craft.

By emphasizing durability, ecological integrity, and respect for natural processes, mud-dyeing presents a compelling framework for the textile industry to transition towards sustainable production. This approach challenges the industry to reconsider its relationship with materials, production methods, and cultural heritage. Mud-dyeing not only preserves a valuable traditional craft but also serves as a model for a sustainable, community-driven approach to design, capable of guiding the global textile industry towards more responsible practices. Through its integration of circular economy principles, bio-based production, and cultural preservation, mud-dyeing offers a low-impact, adaptable solution to current environmental challenges in textile manufacturing, underscoring the value of traditional techniques in addressing modern sustainability goals.

Global Relevance of Traditional Craft

In recent years, the value of traditional crafts in modern sustainability efforts, particularly within the fashion industry, has gained increased recognition. Traditional craft practices often emphasize resource efficiency, local production, and the use of natural materials, aligning closely with contemporary sustainability goals. These practices offer a stark contrast to the fast fashion industry, often criticized for its resource-intensive processes, high carbon footprint, and significant waste generation (Fletcher, 2014). Traditional crafts like mud-dyeing provide an alternative approach that prioritizes craftsmanship, longevity, and the cultural value of textiles, directly addressing some of the critical environmental challenges facing today's fashion industry.

For example, the slow fashion movement, which advocates for high-quality, durable clothing, draws direct inspiration from traditional practices that emphasize the longevity and repairability of textiles (Clark, 2008). This perspective aligns with the values embedded in crafts like mud-dyeing, where each piece is meticulously created using time-honoured methods, fostering a deeper connection between the maker, the materials, and the final product. In this way, traditional crafts contribute to a more mindful and sustainable fashion industry by encouraging consumers to appreciate the craftsmanship and cultural heritage embedded in their clothing. Furthermore, the emphasis on local production and the use of region-specific materials in traditional crafts like mud-dyeing aligns with principles of the circular economy and bio-based production. By using natural dyes, plant-based materials, and closed-loop processes common in traditional dyeing methods, mud-dyeing minimizes reliance on synthetic chemicals and reduces environmental impact (Ellen MacArthur Foundation, 2017). This approach not only aids in reducing global carbon emissions but also supports the preservation of local ecosystems using renewable and biodegradable resources (Kumar and Yadav, 2020). Mud-dyeing exemplifies how traditional methods can be adapted to meet modern environmental standards, offering practical solutions for the textile industry’s current challenges by reducing pollution, enhancing soil health, and promoting resource conservation.

The relevance of traditional crafts extends beyond environmental considerations; these practices also play a crucial role in preserving cultural heritage and providing economic opportunities for local communities (UNESCO, 2013). By maintaining traditional crafts, artisans foster a sense of identity and cultural pride while tapping into the growing market demand for ethically produced, sustainable goods. The interest in handcrafted, culturally rich textiles offers traditional crafts the opportunity to reach global markets, positioning them as a bridge between heritage preservation and sustainable development. In this context, traditional crafts like mud-dyeing not only contribute to ecological sustainability but also align with social and economic sustainability goals by empowering local artisans and supporting regional economies. Through its integration of circular economy principles, bio-based production, and heritage preservation, mud-dyeing exemplifies a sustainable model for the future of the fashion industry. As a practice that embodies both ecological responsibility and cultural significance, mud-dyeing offers the global fashion industry a pathway toward sustainable development, blending tradition with modern sustainability goals to meet today’s pressing environmental challenges.

Interview Insights for the Future

JianPing Xiang's reflections on the future of mud-dyeing reveal a commitment to expanding sustainable practices while preserving the integrity of this traditional craft. She envisions a future where mud-dyeing extends beyond local workshops to influence broader markets, advocating for a model that merges traditional methods with contemporary sustainability demands (Xiang, 2024). Xiang underscores the importance of educating new artisans in mud-dyeing techniques to ensure that the core values of environmental stewardship are preserved as the practice grows. For her, this is not only about maintaining a craft but also about cultivating a deeper understanding of nature's role in textile production—a perspective she sees as increasingly relevant in addressing the world's ecological challenges (Xiang, 2024).

Xiang is particularly focused on the potential of mud-dyeing to meet the growing global demand for eco-friendly textiles. She sees opportunities for international collaboration, where the artisanal nature of mud-dyeing is recognized and valued for its unique qualities and minimal environmental impact (Xiang, 2024). Specific steps Xiang envisions for scaling these sustainable practices include forming partnerships with sustainable fashion brands, joining alliances dedicated to ethical textile production, and exploring global collaborations with organizations that promote environmental conservation. These partnerships would facilitate the introduction of mud-dyeing into wider markets while preserving its traditional values. Mud-dyeing aligns closely with bio-based production principles, relying on renewable, biodegradable resources rather than synthetic chemicals, thereby reducing pollution and fostering resource conservation. By using natural materials in a closed-loop system, Xiang's practices also exemplify the circular economy's emphasis on resource efficiency, waste minimization, and continuous repurposing of materials. However, she stresses that scaling up must not compromise the traditional practices that give mud-dyeing its cultural and ecological significance. In her interview, Xiang discussed balancing small-scale, community-oriented production with exploring avenues for broader reach, suggesting that success in global markets can be achieved by staying true to the roots of the craft (Xiang, 2024). Moreover, Xiang envisions mud-dyeing as a catalyst for changing consumer perceptions of textiles, encouraging a shift away from fast fashion toward a more sustainable and ethically conscious model. The slow fashion movement, which promotes high-quality, durable, and ethically made clothing, aligns with the values embedded in mud-dyeing. Xiang believes that through workshops, educational programs, and strategic collaborations, the philosophy behind mud-dyeing can reach a wider audience, promoting a message of harmony with nature. This approach directly challenges the wasteful practices of conventional textile production, positioning mud-dyeing as a practical solution to the industry's environmental challenges by reducing emissions, conserving resources, and promoting biodegradable materials.

Xiang's vision extends beyond her own workshop, imagining a world where traditional practices like mud-dyeing play a pivotal role in reshaping the textile industry toward greater sustainability and cultural appreciation. By linking the principles of the circular economy and bio-based production with cultural heritage, Xiang's approach offers a sustainable blueprint that can guide the textile industry toward more responsible, low-impact production that honors both ecological and cultural values (Xiang, 2024).

Conclusion

In conclusion, the exploration of mud-dyeing through the lens of JianPing Xiang's practices reveals the deep intersections between traditional craftsmanship and modern sustainability. Xiang's approach demonstrates how ancient techniques can adapt to address contemporary environmental challenges while preserving cultural heritage. Her emphasis on closed-loop systems, the use of natural materials, and resource efficiency aligns with global sustainability models such as the circular economy and bio-based production. By recycling resources like mud and water, she minimizes waste and enhances the ecological health of the land, offering a practical model for sustainable production that contrasts sharply with the resource-intensive practices of industrial dyeing.

Xiang's commitment extends beyond environmental stewardship to include significant socio-economic impacts, particularly in empowering local women artisans. By providing flexible employment opportunities, her workshop fosters community resilience and economic independence, reinforcing the role of traditional crafts in promoting social equity. This empowerment, combined with her dedication to maintaining the integrity of cultural practices, highlights the broader relevance of mud-dyeing in addressing not only environmental concerns but also the social and economic dimensions of sustainability. Looking ahead, Xiang envisions a future where mud-dyeing reaches global markets without losing its roots. To achieve this, she emphasizes the importance of educating new artisans, ensuring that values of environmental care and cultural preservation continue to thrive as the craft gains wider recognition. Specific initiatives, such as forming partnerships with sustainable fashion brands or participating in international collaborations focused on ethical production, could facilitate the scaling of mud-dyeing practices. These partnerships would support global awareness of mud-dyeing while preserving its traditional methods and values. The global shift toward slow fashion further underscores the potential of mud-dyeing to play a pivotal role in transforming the textile industry. As consumers increasingly seek high-quality, ethically produced goods, mud-dyeing's sustainable, artisanal approach aligns perfectly with slow fashion's emphasis on craftsmanship, durability, and mindful consumption. By positioning mud-dyeing within this movement, Xiang's work not only addresses the environmental footprint of textile production but also enriches the consumer's connection to the heritage and ecological responsibility embedded in each piece.

In essence, Xiang's work exemplifies the potential for traditional practices like mud-dyeing to serve as catalysts for a more sustainable and culturally conscious textile industry. This practice offers a blueprint for integrating ancient wisdom with modern sustainability goals, bridging past traditions with future innovation. As such, mud-dyeing not only preserves cultural identity and promotes environmental responsibility but also fosters socio-economic resilience, illuminating how traditional crafts can lead the way toward a more balanced, sustainable, and mindful approach to fashion on a global scale.

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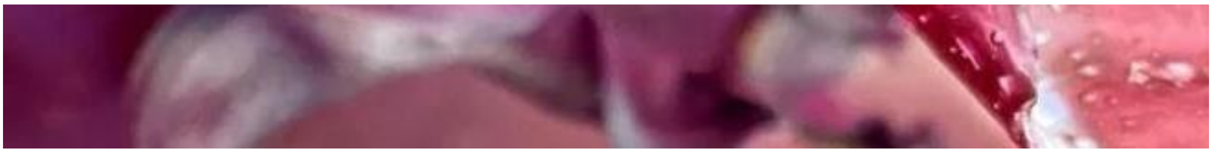

Nurturing Ecological Stewardship in Industrial Design Education

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Keywords: Sustainability, bio based materials, hands on, STEM, industrial design

Introduction

The future of responsible and ecological design demands a new generation of industrial designers equipped with the skills to holistically address complex human needs through sustainable innovation. By integrating hands-on experimentation with bio-based materials into design curricula, educators can cultivate the vital competencies students need to create impactful, user-centered solutions that resonate with evolving expectations around environmental responsibility and STEM skills (Avramescu 123).

At its core, this pedagogical approach embeds the exploration of renewable, biodegradable resources like mycelium, algae, food waste, or beef gelatin into the foundational design skills of user research, ideation, prototyping, and iterative refinement. Students at institutions like the College for Creative Studies have undertaken projects prototyping sustainable furniture and packaging using mushroom mycelium composites ("Bio-Based Materials"). The tactile nature of working directly with these bio-materials facilitates rapid mock-ups, user testing, and feedback integration throughout the user-centered design process (Muszyńska et al. 31). On top of this it provides students with a deeper learning opportunity as they begin to develop and experiment with their own material development.

This hands-on engagement moves beyond just theoretical sustainability metrics, fostering sustainable mindsets and material literacy from the ground up. When Pratt Institute students created lighting products using indigenous Mexican materials like salt and beeswax, they gained first-hand experience with the unique properties, potentials, and challenges of these sustainable resources ("Bio-Based Materials"). The multisensory immersion prompted the designers to rethink unsustainable practices and develop innovative, responsible alternatives tailored to real user needs and contexts.

Moreover, the open-ended exploration of shaping and combining bio-materials sparks the creative inquiry vital for user-centered design thinking. The purposeful "play" of hands-on material manipulation inspires them to ask "what if?" questions that lead to bio-inspired breakthrough ideas and solutions. This creative discovery through making allows designers to push boundaries and uncover new possibilities that cannot be replicated through just visuals or descriptions alone. The focus on developing material also provides a more tangible and smaller scope approach toward creating and understanding that oftentimes is lost within designing a product.

Hands-on bio-material projects facilitate the development of holistic design literacy combining technical knowledge with understanding of a materials' origins, applications, and sensorial qualities. This union of analytical and tactile comprehension is crucial for user-centered design, allowing industrial designers to select and apply materials innovatively to meet the needs of users. The resulting material connoisseurship, as fostered at schools like RISD's Nature Lab, enables more resonant and responsible design work addressing user needs ("How Bio-Based Building

Materials").

Considering the impact material development can have on design students, this led me to implement an entire semester long studio with seniors in industrial design. This allowed me to guide student through material research, exploration, experimentation, discussion on impact, and design implementation of their materials.

Methods:

The studio involved undergraduate design students enrolled in a capstone course focused on bio-based and non-petroleum based materials. A total of 20 students participated, each bringing a unique perspective and background in design.

Course Structure

The 16 week course that met in person 12 hours each week was structured into two main phases: **Material Exploration and Experimentation**, and **Design and**

Implementation. This structure allowed ample time for the design students to really explore the material research and creation component of the studio.

Phase 1: Material Exploration and Experimentation

Objective: To encourage students to explore and experiment with non-petroleum-based materials.

Materials: Students were provided with access to a variety of bio-based materials, including but not limited to, plant fibers, mycelium, bioplastics, and recycled organic waste.

Demonstrations of techniques:

To many students, material development and experimentation can be a very intimidating field of practice. To begin the class, I conducted a number of bio material demonstrations that ranged from Casein Plastic production, beef gelatin bio resin, and agar agar thin film. Each of these demonstrations lasted approximately and hour and provided the needed exposure to material production and experimentation for the students to begin their own research, hypothesizing, and experimentation.

Class Deliverables:

Research: Students conducted literature reviews and case studies on existing bio-based materials and their applications.

Experimentation: Students engaged in hands-on experimentation to create and refine new materials. This involved mixing, molding, and testing various combinations to assess properties such as durability, flexibility, and environmental impact.

Documentation: Students maintained detailed logs of their experiments, documenting processes, results, and observations. This was crucial for the iterative refinement of their materials. Each material developed was cataloged with the following data: exact formula and steps of production, Durometer (Shore A or D), tensile strength, Mohs hardness, Thermoplastic qualities, and flame/heat resistance. This allowed students to have a comprehensive resource for new materials they could reference when it came time for designing objects.

Phase 2: Design and Implementation

Objective: To design functional objects utilizing the bio-based materials developed in
Mid-term Review: At the midpoint of the course, students compiled their research findings and material experiments into a comprehensive report. This served as a foundation for the design phase.

Design Process:

Opportunity Space Identification: Throughout the material experimentation stage of the semester, students were tasked with making observations within daily life for opportunities for design intervention or new product development.

Concept Development: Students brainstormed and sketched potential design concepts that could effectively utilize their materials.

Prototyping: Using their refined materials, students created prototypes of their design concepts. This involved iterative testing and refinement to ensure functionality and aesthetic appeal.

Feedback and Iteration: Students presented their prototypes to peers and instructors for feedback, which informed further iterations and improvements.

Final Presentation: At the end of the course, students presented their final designs, highlighting the material properties, design process, and potential applications.

Results:

The students were very receptive to the entire semester. In the beginning they needed some guidance on the scientific process of experimentation with material development. However, drawing a corollary to the design process made it easy for them to connect the two processes. This step allowed for me to easily explain where and what each stage of the process was intended for and how best for them to utilize each step. Working this way allows for a stronger connection to the STEM world as Industrial Design is often times thought to be a fringe discipline of STEM. Though when we closely evaluate the industrial design and its adherence to a user centered approach towards design and innovation we can clearly see many direct connections to STEM. When we bring in material development and exploration, this connection becomes even stronger and more deliberate to STEM. Students that typically lack the creative confidence for early stage ideation and user investigation were very excited to be doing more of a "hard science" approach towards design. This combination of exploration in material and science allowed the students to deeply investigate the material properties and variables to experiment with. One student went so far as to create over 50 different bio foam samples. Continuously experimenting with various additives to beef gelatin to arrive a desired outcome of a closed cell foam that had adequate impact resistance or cushion.

Other students explored various formulae that would help to create a hard plastic resin compound. These students quickly discovered that the fewer additives resulted in more pure, clear, and more rigid "plastic like" materials. The challenge with these hard resin substitutes was finding a delicate balance with rigidity and flexibility. The more rigid the material, the more easily it broke under minimal stress. The students experimented with adding various plasticizers to the formula to arrive at a material that was parallel to a polyolefin class of plastic.

Finally, there were a few students that took entirely different approaches to the creation and experimentation of the bio based material. These students attempted to either recreate an extremely flexible material that could stretch and inflate similar to latex. While another student used a gelatin bio based material formula to act as a fabric stiffener for a reclaimed wool structure. The student working on the inflatable material had defined an agar agar formula that would work well to be pliable and stretchable similar to latex. However, this material did not lend itself to our DIY molding processes, nor did it want to heat seal to create a volume. Ultimately, a cyanoacrylate glue had to be utilized to bond the seams and create an inflatable volume successfully.

Outside of the material experimentation successes and designed object successes, the most profound result came from the students reflections at the end of the semester. Students that had participated in the bio based material studio realized that so much more was possible when it came to materials and non traditional approaches to science, design, and product creation. The students, collectively, had realized that they did not need to rely on petroleum plastics as the primary material for new product development. They were now more equipped with material development skills and the analysis and synthesis required to explain why a certain material should or should not be utilized for a new product. Plastic does have its place within our world, but so often over history has this material been over sourced and utilized, forgoing other potential material choices. These choices, as the students experienced have impacts both on a large system level and individual scale, and if we can at least show and discuss other possibilities for product material and production, then we may begin to slowly move away from the path we are on now. The path currently set to continue to generate millions of tons of plastic objects and plastic waste that has a profoundly negative impact on our ecology and environments.

These initial experiments and designs are only the beginning for these students. We expect they will look back on this experience for the entirety of their career and think about how they may scale some of the processes and formulae up to be competitive with current petroleum plastic production. Further study of course is needed as we look at scaling these materials and processes up. However, early results from the material exploration state of the semester began to show promise for some of the bio material formulae that could lend them to using existing thermoforming manufacturing processes. Many of the material formulae shared similar thermoplastic properties, and with further experimentation and research, we could find a perfect avenue for adoption within existing tooling and machine processes.

Discussion:

From a STEM education perspective, bio-based material exploration provides an interdisciplinary platform for project-based learning integrating science, technology, engineering principles, and design thinking. Hands-on prototyping with bio-composites allows students to apply concepts from fields like materials science, biotechnology, and sustainable manufacturing. For example, Savannah College of Art and Design students designed and fabricated eco-friendly surfboards using bio-based epoxy resins, combining technical material analysis with user-centered form studies ("Sustainability").

Beyond user-centered processes, bio-based material projects intrinsically involve crosspollination across diverse STEM disciplines. When designing sustainable packaging solutions using mycelium at the Biomaterials Lab at Pennsylvania College of Art & Design, students must collaborate across fields like biotechnology, industrial design, and environmental science ("The Benefits"). Building these vital interdisciplinary skills equips designers to address the multifaceted challenges of sustainable innovation. This crossfunctional integration reflects modern product development realities, allowing designers to adapt to changing business needs.

In the real world, major companies like Dell, Nike, Puma, and Philips are already utilizing hands-on materials exploration and sustainable bio-materials in their design processes. Dell incorporates materials like bamboo and mushroom packaging ("How Bio-Based Building Materials"). Nike has an entire Explore Team dedicated to manipulating sustainable textiles and composites ("Sustainability"). Puma's urban mobility concepts emerged from hands-on prototyping with new eco-materials ("How Bio-Based Building Materials"). Philips' designers can experiment with bio-based materials like wood, wool, and bio-plastics in their "Do Explore" lab. Graduates prepared through immersive, experimental curricula will emerge ready to join these cutting-edge sustainable innovation efforts.

Ultimately, by interweaving bio-based materials into the core pedagogy of industrial design education through hands-on experimentation, educators can shape the next generation of creative, sustainable thinkers and STEM problem-solvers. Graduates will emerge with the holistic material literacy, bio-inspired creativity, user-centered processes, and cross-disciplinary collaboration abilities to develop impactful solutions tailored to the evolving needs of users, businesses, and the planet itself.

As society continually raises expectations around environmental responsibility, sustainable innovation, and STEM skills, designers prepared through this immersive, experimental approach will stay adaptable and responsive. The future of design demands a holistic perspective integrating human needs and responsible material utilization - and hands-on bio-material exploration provides the vital skills for creating resonant, eco-conscious solutions centered on both human and ecological contexts.

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Exploring the Nano World: Engineering & Design with Biology

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Introduction

This paper outlines the capacity of the scientific domain of engineering biology to produce biologically based devices and to become a new manufacturing base. This will be illustrated by discussing the design of a bio-nanostepping motor and a discussion as to how this device can be produced, evaluated and mass-produced. This paper also presents the ideas and concepts on which this is based.

We are in what is being referred to as the 4th industrial revolution, with one of the major emerging platforms being the use of biological materials and applying the principles and processes to develop a new sustainable manufacturing base. This is possible due to recent major scientific and engineering developments (Byrne et al. 2018).

Living organisms harness biomolecular self-organisation to construct and manipulate often intricate machinery and super-structures at the nanoscale. Being able to have controlled manipulation of the shape, size and interactions of such super-molecular building blocks opens up extensive potential for in vitro artificial self-assembled nanoscale material. As such, these organic units can be incorporated into a living building.

The current industrial manufacturing context is one that faces environmental, political, geographical and economic factors. Society is also changing its perception of global energy use and manufacturing practice (RAE report 2019). There is a concomitant movement towards reducing the size of components to the nanometer scale, using and manipulating individual molecules or atoms to perform specific tasks. Technological developments, particularly in using biology, are being applied to the challenges faced by human society. A specific reason for this is that biological molecules and systems processes have advantages over man-made components and devices and current manufacturing methods. The advantages include being able to operate at the atomic/molecular level, often using energy more efficiently, not requiring high temperatures or pressures to operate; in addition, the self-assembling and regulating processes are less technologically complex and less environmentally polluting (Clomburg et al. 2017, Byrne et al. 2018, Subramani and Ahmed 2018) Biological materials, in certain circumstances, also have another major advantage over non-biological materials: this is their biodegradability (UK BIA report 2018). A major challenge is to extract and then re-assemble these components into an integrated working mechanism; furthermore, any device needs to be controllable.

All machines need energy to work. The most abundant, freely available and environmentally friendly energy source is solar energy. Much of the biological world relies on photosynthesis to provide the energy they need to operate and live. The 'light reactions of photosynthesis' involving chlorophyll are responsible for trapping visible light energy and moving the energy within the plant with an efficiency of more than 90%. This energy could then be transformed into other types of energy, such as electrical or the chemical energy of adenosine triphosphate, ATP (Shevela et al. 2023).

In the last few years techniques have developed such that we can now detect an individual molecule. These can also obtain information on the detailed structure, properties and behaviour of these molecules. Modern super-resolution microscopic techniques enable live cells to be investigated, thus providing dynamic information on biological processes (Schermelleh et al. 2019, Khater et al. 2020). As a result, we can also manipulate biological systems at the molecular level. This enables us to view biology as a big tool box similar to a

Meccano set (UK BIA report 2018) with about 85 million types of proteins (https://biology.stackexchange.com/questions/58868/how-many-proteins-are-in-the-earths-proteome) being pieces which can be combined and assembled into a host of different configurations. New materials, devices and systems can be designed and produced that do not exist naturally. The new super-resolution microscope techniques are pivotal tools in synthetic and engineering biology (Lv et al. 2022). Within these domains, two main approaches are used. One is the top-down approach, which uses the biological systems inherent in living cells to produce macro-molecular assemblies. This approach is based on the techniques of genetic engineering, cellular and molecular biology. The alternative is the bottom-up approach, which does not use living cells to assemble complex biological systems (Figure 1). Here the innate ability of biological molecules to self-assemble is used, along with chemical synthesis and the physical manipulation of molecules (Damiati 2019).

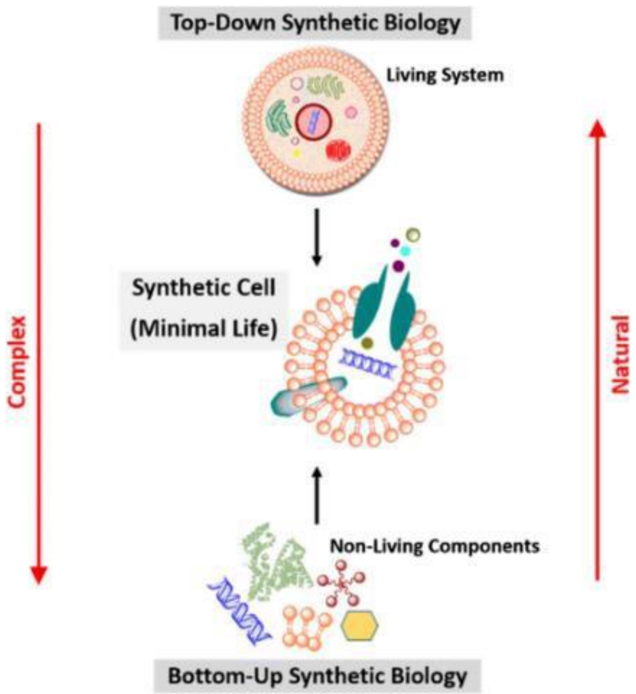

Fig 1. Damiati (2019) Diagram illustrating the two main approaches used in synthetic biology

The bionanomachine presented here is designed to move a tubule or rod in 8nm controllable steps and to operate outside of a cell. The biological principles and materials of photosynthetic light (energy) harvesting and transfer are used in creating this device. This requires the use of the ATP synthase complex for ATP production and Kinesin motor protein movement. To reverse, or reset, the rod back to its starting position, a genetically engineered kinesin, which is activated by blue light to reverse the direction of movement of the kinesin, could be used (Nakamura et al. 2014).

There are three sections to this device that can be used either in an independent (modular) concept or integrated as a functioning device (see Figure 2). The three sections are:-

A) Light harvesting and energy transfer conduit (in Figure 2 coloured green)

B) Energy conversion producing ATP. (in Figure 2 coloured blue)

C) Mechanical translation (in Figure 2 coloured red)

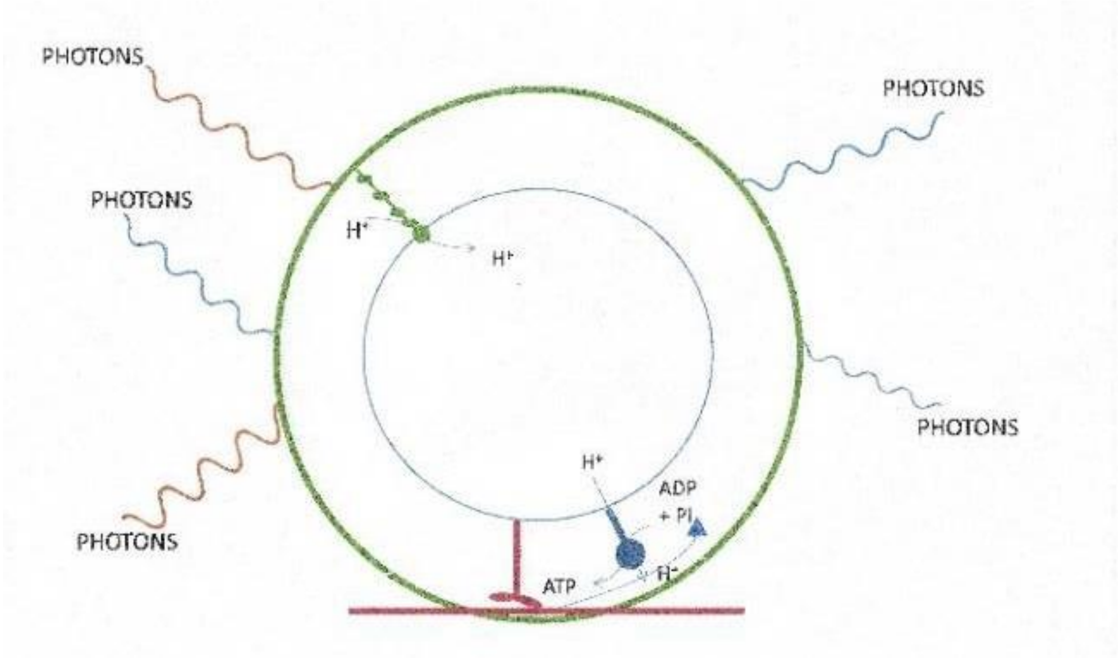

Fig 2. Sparrow (no date) Diagram showing the architecture of a bionanostepping motor. The structures in green are a membrane incorporating LHCII with an energy conduit linking the outer to an inner membrane. The components in blue are an inner membrane with an incorporated ATP synthase complex to generate ATP. The red components are a kinesin attached to a nanorod. The kinesin heads produce a step in the presence of ATP which then pushes the rod. The intermembrane space encapsulates ATP/ADP/Pi to enable ATP recycling.

One of the major challenges would be to assemble the components into an integrated working mechanism. It is proposed to employ molecular self-assembly, which is a property innate to many biological molecules. To produce such a complex macro-molecular biological architecture requires controlled, sequential, and pre-determined molecular self-assembly. It is proposed to use droplet based micro-fluidics to automate the assembly of this bionanostepping motor machine. It is also proposed to, where possible, develop integrated diagnostics and sorting systems. This will be to assay and then select components with the required technical specifications to allow each component to progress onto the next assembly stage. Then undertake a final quality assessment of the fully assemble machine.

Methodology

This section outlines the concepts on which the assembly of a biologically based nanosized machine is based, rather than specific methodologies or techniques of its construction.

Biological Molecular Self-Assembly

This is a property of many biological molecules that, by their random movement, produce complex structures. Self-assembly is where molecules spontaneously and autonomously form non-covalently bonded stable, structured aggregates. The structures are stabilised via weak electrostatic interactions such as hydrogen bonds, hydrophobic and hydrophilic interactions and Van der Waals forces. This is often facilitated by the assembling molecules having specific complementary properties such as surface shape, functionality and charge. Self-assembly can be either static or dynamic. Static self-assembly is where, once the final stable state is achieved, no energy is required to maintain it, whereas dynamic self-assembly requires energy to maintain this state. There is also a distinction between inter- and intra-molecular self-assembly. Intra- molecular assembly is where large multi-molecular structures are produced (Karthikeyan and Waqar 2018).

Self-assembly of the light harvesting array: this would be a connective pool of chlorophyll light- harvesting complexes (LHC). Chlorophyll is a natural pigment used to absorb light and transfer the absorbed energy around a system. To accomplish this, the chlorophylls are arranged in a specific configuration, which is achieved by being attached to proteins forming an LHC. These complexes are then correctly orientated for efficient energy transfer by being incorporated into a lipid membrane called the thylakoid membrane (Shevela et al. 2023). For several years researchers have been exploring and, using self-assembly, producing artificial light harvesting systems using natural and synthetic pigments (Katterle et al. 2007, Wu et al. 2024).

Production of the energy transfer conduits: Zhou et al. (2019) demonstrated that directional long range energy transfer is possible and efficient (Figure 3). They used a double-stranded DNA- template (dsDNA) with conjugated dye aggregates of benzothiazole cyanine dye K21.

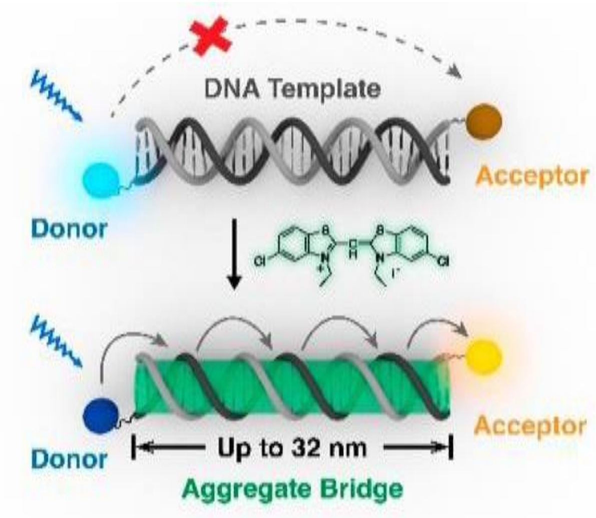

Fig 3. Zhou et al. (2019) Diagram showing an artificial light harvesting system with donor and acceptor terminal conjugated Alexa Fluor dyes along a dye aggregate bridge.

Figure 3 presents the energy transfer conduit as developed by Zhou et al. (2019). Here, this would need to be modified, it is proposed to use chlorophyll or light-harvesting complexes instead of benzothiazole cyanine dye K21. At the donor terminal end, Alexa Fluor dye could be substituted by a chlorophyll molecule. However, at the acceptor terminal end the Alexa Fluor dye would need to be substituted for a proton pump. For this, a number of different reaction centres could be used such as photosystem I (PSI), and photosystem II (PSII) from higher plants or photosynthetic bacteria, or potentially, bacteriorhodopsin could be used.

Production of double vesicles: within biological systems many functions are regulated and managed via proteins, including enzymes. To ensure these proteins are able to correctly co-ordinate with one another they are often incorporated within a membrane. Membranes are also used to compartmentalised into functional areas called organelles. These membranes are composed primarily of lipids. Lipid molecules are hydrocarbon based and typically have two domains, one is hydrophobic (the tail) and a hydrophilic head. This configuration means that when interacting with water the hydrophobic tails will associate together away from the water molecules with the hydrophilic heads interacting and associated with the water molecules. In this way lipids will naturally self-assemble into bilayer membranes and at certain concentrations they naturally form vesicles (Watson 2015). Microfluidics are used to produce single and multivesicular vesicles where the lipid composition and contents of each vesicle can be independently controlled (Damiati 2019).

Assembly of the ATP generating system: in the mitochondria the ATP synthase complex is attached to the mitochondrial membrane. Thus, in this device, an ATP synthase introduced to a lipid membrane should self-assemble into the vesicle membrane. The core of this device is based on a modified version of the Steinberg-Yfrach et al. (1998) system of a liposome with an incorporated light activated reaction centre and an ATP synthase complex. This part of the device converts the excitation energy from light absorption into the biologically important chemical energy molecule of ATP. The proton pump mechanism (a reaction centre or bacteriorhodopsin) creates a proton motive force (a proton concentration gradient and potential difference across the membrane), which is used to activate an ATP synthase complex. This then uses the proton motive force to couple the substrates adenosine diphosphate (ADP) and an inorganic phosphate (Pi) to produce ATP. This is based on the system developed by Steinberg- Yfrach et al. in 1998. The modification for this device is that the proton pump and the ATP synthase are attached to the inner vesicle of a double vesicle system. The substrates ADP, Pi and ATP and the protons generating the PMF are enclosed within the space between the two vesicles. Thus, these substances can be recycled.

Assembly of Kinesin attachment to a vesicle and microtubule: Kinesin motor proteins are used in all eukaryotic cells to transport a variety of materials, termed cargoes, such as proteins in a vesicle. Kinesins are a superfamily of motor proteins that undergo ATP-dependent movement along a microtubule. A microtubule is a 25nm tube like structure which serve as intracellular rails on which motor proteins travel from one part of a cell to another. Microtubules are polar in that they have a fast-growing end, which is termed the plus end. The other non-growing end is referred to as the minus end. Kinesins move in a single direction from the minus to the plus end of the tubule. On hydrolysis of the ATP the motor produces a step-wise movement along the microtubule going from one binding site and then onto the next. When Kinesin moves, the head that is bound to the tubulin is not released until the other head binds to the next binding site along the tubulin. One head is always bound to the microtubule. The Kinesin motor domain binds to the tubulin at 8nm intervals. (Yildiz 2024)

Microfluidics For Controlled Molecular Self-Assembly

Microfluidic systems have channel dimensions of tens to hundreds of micrometres that enables them to manipulate nano- and pico-litre volumes of liquid. Such devices enable the physical and chemical properties of fluids to be controlled and are powerful tools for regulating the processes of self-assembly. These systems boost the efficacy of mixing, such that efficient, proper and complete mixing of liquids is obtained, enabling the fine control of parameters such as temperature. Microfluidic devices can be used in manufacturing self-assembly molecules producing stable self-assembled structures. Microfluidics is a powerful technology for controlling the bottom-up self-assembly of nano- and micro-scale structures (Dou et al. 2017). Microfluidics offer significant advantages over conventional methods, as it provides kinetic control, allowing thousands of molecular molecules to be assembled into discrete supramolecular structures. (Khoneini et al. 2021).

Droplet microfluidics is the encapsulation of reagents encapsulated in an emulsion of discrete droplets, typically an aqueous phase in oil. With this technique, huge quantities of uniform droplets can be produced allowing high throughput analysis. The main advantage of droplet microfluidics is its highly multiplex capabilities. As reactions are confined to independent droplets, each of a few nanolitres, it is possible for thousands of reactions, or self-assembly events, to take place concurrently. As each droplet is discrete and independent, the reagents present inside a droplet can be readily tailored to fit a variety of needs. As this technique employs droplets of very small volumes, the diffusion time for a molecule is quicker than with conventional systems, leading to quicker reaction times (Convery and Gadegaard 2019). The ability to precisely manipulate droplets after their generation is key in maximising their utility as reaction, assay or storage vessels (Suea-Ngam et al. 2019). The benefits of droplet-based microfluidic reactors over continuous-flow and flask-based methods for material synthesis are well-recognised and, if made and operated in parallel over prolonged periods, would be a relatively simple way to up-scale production (Jain et al. 2002). Once droplets have been produced there are a range of manipulation techniques that can be undertaken: there are passive and active techniques, as shown in Figure 4. Droplet- based microfluidic platforms typically incorporate many functional components that allow complex experiments on a range of chemical and biological systems. This means that once formed droplets, and their internal contents, can be dynamically changed within the microfluidic device. For example, pico-injection involves injecting a specific volume of a chemical, at a pre-designated point, into a droplet. The ability to generate and analyse large numbers of droplets at high-throughput is a particular strength of droplet microfluidics (Suea-Ngam et al. 2019).

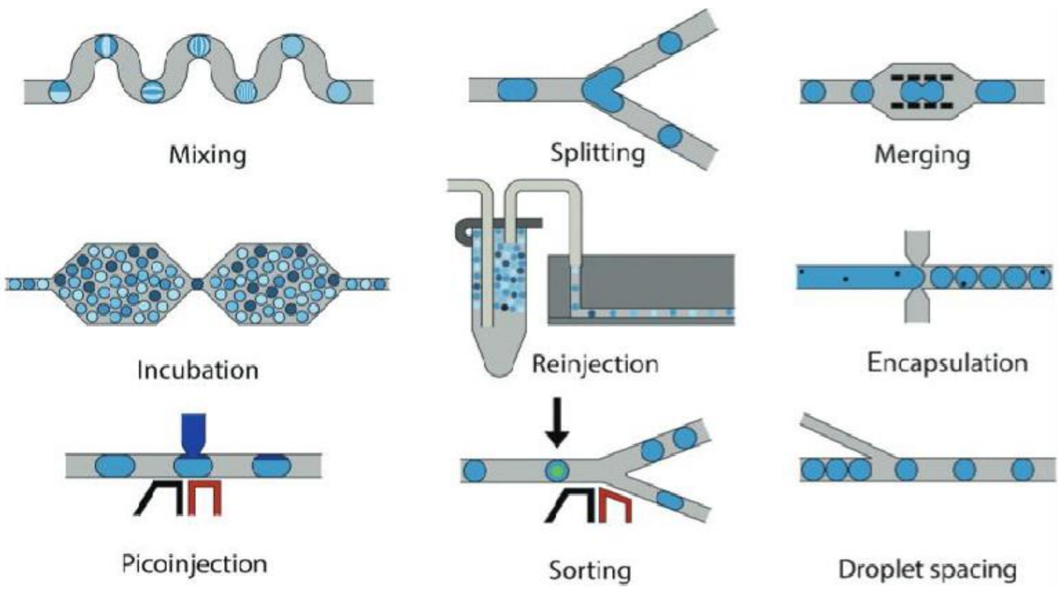

Fig 4. Suea-Ngam et al. (2019). Diagrams illustrating different channel geometries to undertake a range of droplet manipulations within a microfluidic device.

Multiple layer membrane systems have been produced using microfluidics for some time. (Matosevic and Paegel 2013)

Detection in microfluidic chips: analysis of samples is often required to monitor biological processes and, as microfluidics is being proposed as the platform technology to assemble biological components it would be useful to be able to analyse the assembly at critical stages within the same system. Incorporating optical detection methods such as absorbance and fluorescence within a microfluidic device is commonly used (Richter et al. 2023)

Diagnostics of Energy Transfer Conduit

Below is an outline of how a component such as the energy transfer conduit could be assayed as an internal diagnostic process in a microfluidic device. In this case, the assay is to ensure that energy is flowing from the donator to the acceptor terminals through the intermediary pigments.

In the system shown in figure 3, Zhou et al. (2019) reported that energy transfer was demonstrated by attaching an Alexa Fluor 350 molecule as a donor and then Alexa Fluor 555 as a terminal acceptor. Here chlorophyll molecules will be used instead of benzothiazole cyanine dye K21. Coupling fluorophore dyes to light-harvesting systems has been undertaken with Texas Red (Hancock et al. 2021). and Alexa 647 (Yoneda et al. 2015) (see figure 5). This demonstrated that energy transfer between the fluorophore and light-harvesting complexes is between 60 – 92% efficient. Here I also propose to use Alexa Fluor 350 as the donor with Alexa Fluor 750 as the terminal acceptor. Each of the different pigment components should have spectrally separate absorption and fluorescence (light emitting) characteristics such that each component is spectrally differentiated and can be specifically identified. For the donor terminal end, Alexa Fluor 350 is suitable as it absorbs light at 343nm (ultra-violet) and emits at a wavelength to excite the chlorophyll, and Alexa Fluor 750 is suitable for the acceptor terminal end as it absorbs in the wavelength region of chlorophyll fluorescence, and it has a peak fluorescence at 775nm (infra-red) (Bell et al 2015). When the dsDNA-HL conjugates are illuminated with 340nm light, and if fluorescence is observed in the 770-800nm (infra-red) region, this would show that energy has been transferred along the conduit. This is an adaptation of a widely used technique called FRET (Fluorescence Resonance Energy Transfer) to extend this energy transfer process; Zhou et al. 2019 demonstrated the principal concept of this idea was possible (see figure 3). If the Alexa Fluor 350 is not correctly coupled to the chlorophyll, then fluorescence between 400 – 500nm (blue light) will be observed. If any of the chlorophyll's are not properly connected, then fluorescence at 700nm (red light) would be observed.

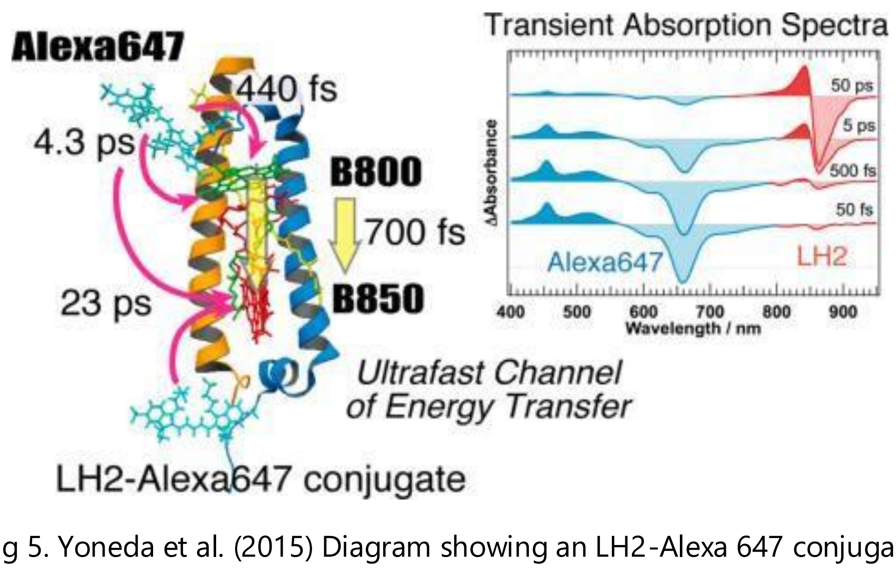

Fig 5. Yoneda et al. (2015) Diagram showing an LH2-Alexa 647 conjugate

Results

Researchers have been able to construct a number of the sub-components of the machine presented here. For example, building lipid vesicles and multi-layer vesicles using microfluidics has been possible for a number of years (Diamanti 2019). Similarly, many researchers have been experimenting with and producing artificial light harvesting arrays capable of energy transfer. These have been using natural and synthetic pigments in a variety of membrane environments (Katterle et al. 2007, Wu et al. 2024). The directed energy conduit has been designed and produced by Zhou et al. (2019). A modified version of this is proposed to be the basis for the energy conduit in the bionanostepping motor presented in this paper. ATP production outside of a cell has been shown to be possibly by Steinberg-Yfrach et al. (1998) when they attached an ATP synthase complex to a lipid vesicle with an incorporated bacteriorhodopsin as a proton pump. They were able to show light induced proton pumping to produce a proton motive force (PMF) which then generated ATP. Lu and Jewett (2023) have shown that ATP / ADP recycling within an encapsulate vesicle system in an enclosed space is possible.

Discussion

This paper outlines a potential architecture of a bionanomachine (Figure 1). Importantly, the principles on which it could operate and the processes by which it could be mass produced.

The flow of energy through the system is as follows. Light is the primary energy to drive the machine and is harvested by the photosynthetic light harvesting pigments incorporated within the outer membrane of a vesicle. The excitation energy is then transferred to the inner membrane via a specific directional energy transfer conduit. At the terminal end of the conduit is a photoactive proton pump, potentially a bacteriorhodopsin. On activation, the bacteriorhodopsin pumps protons from the space between the two membrane vesicles and into the inner vesicle space. This creates a proton motive force (PMT) within the inner vesicle. The PMT then activates the ATP synthase complex to couple ADP and Pi to form ATP. The pre-cursors ADP and Pi are encapsulated within the inner membrane space. As the machine is carrying its own components to generate ATP and is thus independent of a living cell to work. ATP is the biological molecule that provides energy for many biological energy requiring processes and thus can potentially be adapted to activate and power a number of processes. In the process of imparting the chemical energy of ATP to a biological process the ATP is hydrolysed back to ADP and Pi. With this device as these processes take place within the inter membrane space the ADP and Pi are maintained in an enclosed space and can thus be recycled to produce more ATP – in this case a kinesin motor protein. Kinesin has two heads which move along a tube in a stepwise manner requiring 1 ATP per step. In the cell the kinesin moves along the tubule; the kinesin is fixed and so the tubule moves in the direction of the steps. The control of the machine is through light; if the light is on, then energy flows through the system, resulting in the movement of the tube, if the light is turned off then the machine stops. Light is a very controllable energy source. Thus, it would be possible to calculate the amount of light energy would need to be delivered to the machine to produce 1 ATP and thus make 1 step, or, if more steps are required, then the corresponding amount of energy needs to be supplied. For repeated use of this machine, the tubule also needs to be able to reverse the movement of the tube. A group have recently genetically modified a kinesin by incorporating a blue light activated switch at the hinge between the stalk and the heads (Nakamura et al. 2014). When activated by blue light this reverses the heads and thus the direction of movement of the kinesin. In this way this machine can be used as a piston.

With regards the mass production of the machine here it is proposed to use droplet microfluidics. This requires a suitable channel design, incorporating repositories for the component molecules, micro-reactors to undertake the controlled self-assembly processes, valves to control the flow of the droplets and components taken from a repository and to a micro-reactor, as well as detectors to regulate the quantities of components required for each assembly stage. Also incorporated into the chip design could be internal diagnostics to analyse the initial components, the assembled components and then the final completed machine.

As mentioned previously, once ATP has been produced then a range of biological molecules and processes can be activated. Many enzymes, motor proteins and active transport mechanism can be controlled. Thus, there is a great number of potential applications that this technology could be applied to.

As described above, once there is such a device, this technology can be applied to manufacture novel materials and devices – for example, in the medical field, such as minimal invasive surgery particularly on tissues or organs that are very delicate. Being sub-cellular in size, such devices could be injected into the body and then directed to the site to undertake the surgical manipulation required. Once this has been completed, being biological, the device can be programmed to degrade and be incorporated into the cellular structure.

The potential application of such a device are:

- A drug delivery system.

- Precision nano-engineering.

- Minimal invasive nano-surgery of delicate tissues like the retina, lungs or alimentary canal.

- Detoxification of polluted environmental sites.

This technology, while in its infancy, can thus achieve major advances in human and environmental well-being. Its use requires not only scientific and technological understanding, but also creativity and imagination in rethinking how we address significant problems faced by humanity.

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Can Ancient Practices be entitled Biodesign?

A terminology proposal based on Ancestral Knowledge and Traditional Practices

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Keywords: Terminology; Ancestral Knowledge; Traditional Practices; Biodesign; Biocraft

Introduction

What are vernacular knowledge and traditional practices?

Vernacular knowledge embodies the organic and natural essence of man's harmonious relationship with the surrounding environment or the Roman mythological concept of genius loci. It differs due to the unique constraints – geographic, economic, social, historical and cultural – of the places and population group that holds it, summarizing local materials, resources and techniques while adapting to climatic specificities and responding to the family structure, respective economic activity and community customs (Cerqueira, 2005).

Traditional practices refer to the acts and wisdom generated over many generations by local communities. They honor ancestral knowledge to ensure its continuation, mainly of those with positive physical, emotional, and/or spiritual relationships with the surrounding environment and those fostering pride and identity.

Therefore, vernacular knowledge and traditional practices are related to memory and the non-erasure of culture and values. They encompass Julia Watson's term Lo—TEK, derived from Traditional Ecological Knowledge, a cumulative body of multigenerational knowledge, practices, and beliefs. Lo-TEK is "an exploration of lesser-known local technologies, indigenous cultural practices, and mythologies passed down through generations. In a world that often values homogeneity, Lo-TEK reframes indigeneity as an evolutionary extension of life in harmony with nature" (Watson, 2019, p.17).

It leads to Indigenous Knowledge place-based knowledge accumulated across (Jessen et al., 2021, p. 93) or Radical Indigenism, a term that "dares to suggest, as its fundamental theoretical premise, that American Indian peoples possess philosophies of knowledge that can be understood as rationalities – articulable, coherent logics for ordering and knowing the world" (Garroutte, 2018, p. 170).

All of them – ancestral | vernacular| indigenous knowledge, and traditional practices – are not static relics of the past that must be preserved. Instead, they are dynamic and evolving, offering us the opportunity to learn from and reinvent our traditions without losing our intangible cultural heritage, one that is "transmitted from generation to generation, is constantly recreated by communities and groups in response to their environment, their interaction with nature and their history, and provides them with a sense of identity and continuity, thus promoting respect for cultural diversity and human creativity" (https://ich.unesco.org/en/convention).

They are also part of a belief system derived from written, oral, and spiritual epistemologies, as explained in Jessen's diagram of conceptual foundations and approaches of Indigenous knowledge and Western science in ecology and evolution (Fig. 1), and are of interest nowadays because they present a close relationship between what is currently defined as the three pillars of sustainability (economy, society, and environment).

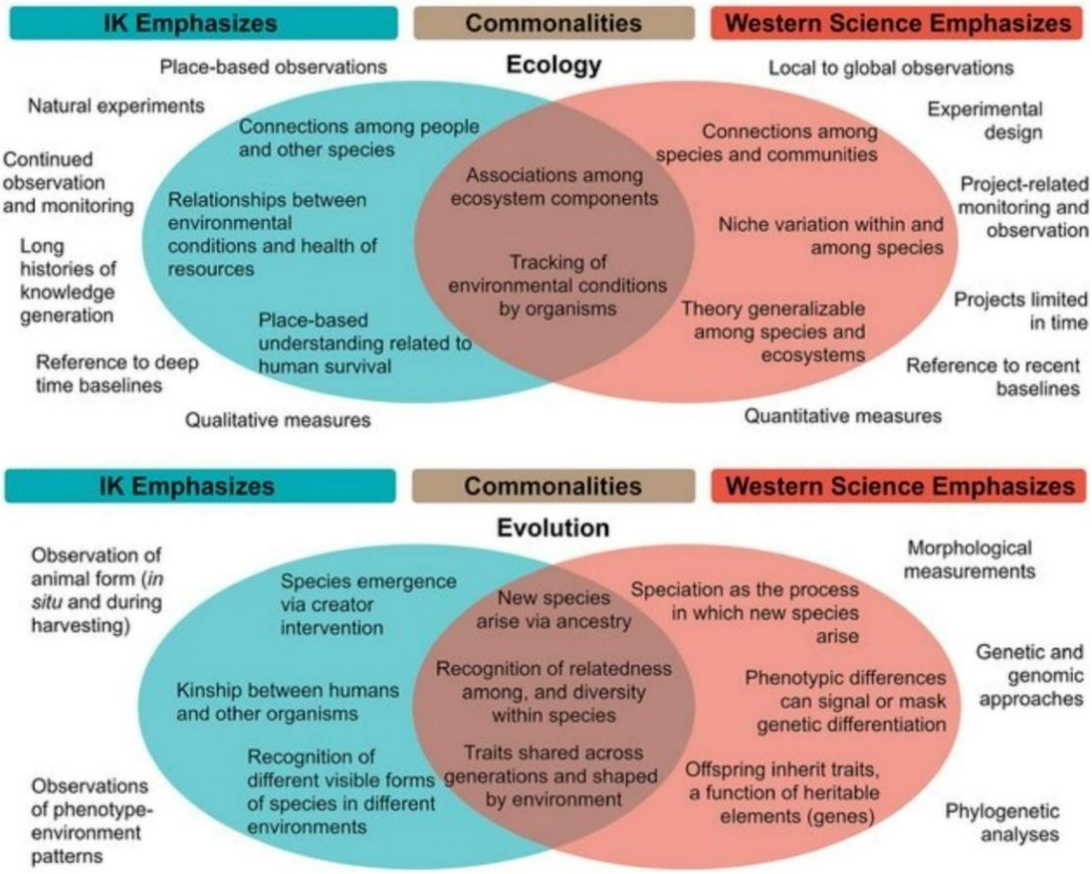

Fig 1. Jessen et al. (2021) A framework with the connections and differences between Indigenous Knowledge and Western Science. p.97.

What is Biodesign?

Biodesign emerges as a contemporary design strategy characterized by the collaboration between designers and living organisms, transcending conventional paradigms of product design conception and manufacturing (Colani, 1984; Karana & Camere, 2017; Myers, 2018; Camere & Karana, 2018; Collet, 2021). Central to its ethos is the imperative to lower environmental impact, embodying a response to contemporary society's prevailing ecological crisis.

One of the critical objectives of Biodesign is to cultivate material and product alternatives that not only foster ecosystem sustainability and resilience but also inspire a new way of thinking. Biodesign extends its view to encompass the realm of biomaterials, employing living organisms such as bacteria, mycelium, and algae as sources, renewable resources, and once-living materials. These biomaterials encapsulate ecology and resource efficiency principles intrinsic to Biodesign's ideology. Agro-industrial byproducts or residues from culinary enterprises, such as eggshells and fruit peels, also serve as fundamental substrates for biomaterial fabrication.

In 2015, Oxman discussed this integration trend or transition from binary codes to biological systems. In 2016, Dade-Robertson pointed out that we are moving towards an era in which a new relationship occurs between biology and the built world as co-creators of new material structures (p.9). In 2021, Collet framed it in Fig. 2, explaining how designers can work with nature and become biodesigners.

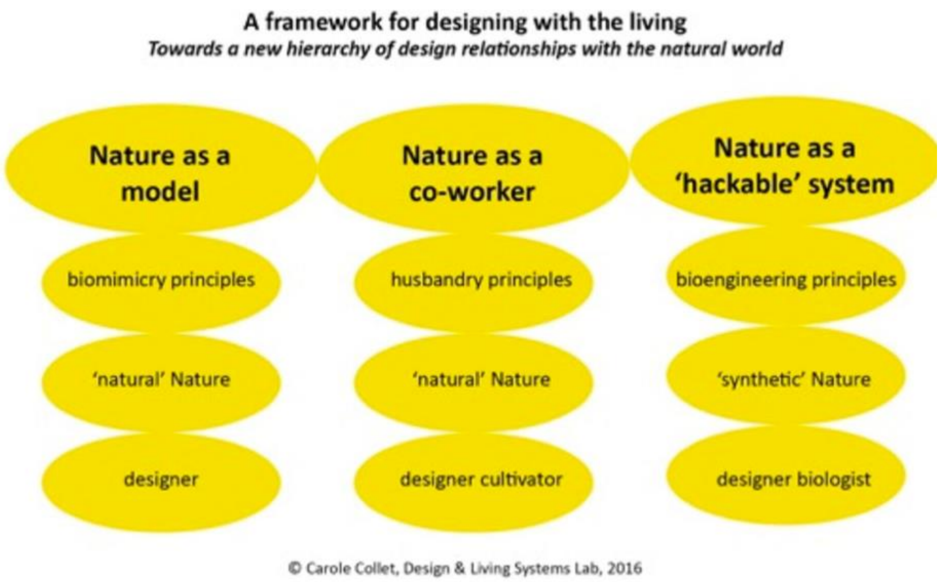

Fig 2. Collet (2021) A framework for designing with the living: toward a new hierarchy of design relationships with the natural world. p.1334

Ancient Practices & Biodesign

The intertwining of traditional knowledge and ancient practices with Biodesign is presented in William Myers' seminal work, "Biodesign: Nature, Science, Creativity," (2018), initially published in 2012. One of the book examples, differing from all other cases displayed, is the "Root Bridges of Meghalaya" in northeastern India (Fig. 3). These bridges, shaped through the ancient practice of guiding the roots of the local Ficus elastica trees, serve as a testament to the potential of engineering living structures and their endurance through time.

Fig 3. Myers (2018) The "Root Bridges of Meghalaya". p.31.

The Root Bridges of Meghalaya singular example within Myers' compendium highlights the intrinsic value of Indigenous technologies as part of a predominantly contemporary design discourse. It is a compelling case study for our research question: Can an ancient practice, predating and existing outside the scientific framework, be classified as "Biodesign?" This paper navigates the complex interplay between tradition and innovation through critical reflection and interdisciplinary dialogue. Doing so fosters a more inclusive and equitable discourse within the evolving landscape of Biodesign and Ancestral Knowledge or Traditional Practices and proposes a more fitting nomenclature.

Methodology

The hypothesis is that there is an alignment between the principles inherent in Ancient Practices and those from design's contemporary discourse. We conceptually relied on a recent publication by archaeologist Eduardo Neves and urban researcher Rodrigo Castriota that delves into a pertinent terminology discussion emanating from the Amazonian territory.

Then, an examination of different case studies elucidated this investigation's complexities. The case study represents a deliberate effort to delve deeper into the nuances of the discourse between Ancient Practices & Biodesign and were excerpted from Lo—TEK (Watson, 2019), Learning from Vernacular (Vitra Design Museum, 2013), BIO27 | Super Vernaculars (7th Biennial of Design, 2022), and What Design Can Do Conference at Mexico City (2023).

We followed a three-stage method: selecting case studies, analyzing converging points, and interpreting the results. Four cases were selected according to three main criteria, anchored by a pluriversal approach (Escobar, 2018), which promotes new perspectives, challenging the dominant paradigm and emphasizing the need for a more integrative perception of the world.

The first criterion was Ancient Practices that unveil natural materials. We draw on Camere and Karana's approaches to guide our selection process, arguing "the various roles that Nature can take in design, such as in rethinking the production of artifacts in a more efficient/sustainable way" (2017, p.102).

The second criterion was the focus on local techniques. "This active engagement in materials fabrication extends designers' control over product sustainability, as they can better handle materials' sourcing (e.g. favoring local, unused raw materials), their application in products (e.g. reducing amount of materials and waste) and end-of-life stage (e.g., crafting unique, non-repeatable aesthetics that stimulates users' emotional attachment to products)" (Camere & Karana, 2018, p.572).

Finally, the third criterion was the geographical location of each case, from the understanding that cultural issue is essential in studying the inclusion of different mastery in an epistemologically diverse space anchored in traditional local knowledge.

Theoretical base and case studies

The “tropical urbanism” and the “Amerindian cities”

In the Amazonian context, Neves & Castriota (2023) formalized a discussion surrounding the terminology associated with ancient practices and reframed conceptual frameworks to accommodate diverse cultural perspectives. For these authors, the Amazon region should be recognized as an ancient centre of plant domestication and cultivation, with intense production of agrobiodiversity: "Just like a garden, the Amazon forests are a social product and result from the combination of biophysical processes and human actions, whether premeditated or not." (Neves & Castriota, 2023, p.65).

Therefore, contrary to historical misconceptions perpetuated by colonial explorers, it is now widely recognized that the Amazon Forest was not an untouched wilderness (Castro, 2013). Before European arrival, Indigenous populations inhabiting the region fostered a profound and intricate relationship with the botanical environment, actively shaping the forest configuration and significantly contributing to its remarkable biodiversity (Neves, 2002; Furquim, 2020).

These authors contend that the Amazonian landscape comprises expansive and interconnected spaces where the boundaries between nature and culture are blurred. They challenged conventional paradigms, lamenting the inadequacy of archaeological terminology in capturing the complexity of these structures.

Neves & Castriota questioned whether these complex Amerindian settlements could be called "cities" and how to analyze contexts in which the "urban" centres produced forests, and the limits of their surroundings were subtle and gradual. "Can we talk about "Amerindian cities," or are we reproducing old ethnocentrisms?" they have asked (2023, p.71).

In light of these considerations, the authors suggest an expanded discourse on "tropical urbanism" grounded in contemporary archaeological and archaeobotanical discoveries. Specifically, within the Amazonian context, they propose a reevaluation in which ancient "urbanisms" are not confined solely to settlements but encompass the surrounding trails, fields, chestnut groves, capoeiras, and camps, together with the flexible movements and practices that characterized them (2023, p. 65).

Expanding upon their discourse of renaming urbanization, the authors pose thought-provoking questions, challenging conventional understandings of the modern colonial apparatus of exploitation. They interrogate whether the built environment of ancient Amerindian people holds insights that could inform the construction of a future that is inherently urban yet divergent from industrial paradigms.

In considering the legacy of Indigenous people, the authors highlight the potential for tension and destabilization of categories related to industrialization. They contend that through millennia of practice, Indigenous societies have demonstrated a capacity for abundance production without succumbing to industrial imperatives. In this light, they provocatively inquire: What lessons might be learned from "ancestral Amerindian urbanism"? How can these insights be mobilized to challenge and reconstruct contemporary practices?

The impasse in practice: four case studies

Biodesign and the Peruvian Totora Reed town - from Watson, 2019

The Uro community in Peru, deeply rooted in their environment, has made environmental sustainability a cornerstone of their ancestral wisdom. They have the ability and knowledge to fashion clothes, beds, houses, boats, islands, and platforms out of reed, a tradition that began as a means of protection from hostile neighboring tribes.

The totora reed bundle (Schoenoplectus californicus) is an organic and local material.

According to Paredes and Hopkins (2018, p.169), "evidence from the recent past and the historical and pre-Hispanic periods suggests that some aspects of the technology of reed vessel construction have persisted whereas others have been modified." To form the base module for island construction (Fig. 4), "Eucalyptus stakes are driven into blocks of the root and used to lash the bricks together, creating a two-meter deep floating foundation. Over time, bricks grow together, forming a single living base layer" (Watson, 2019, p.278).

Fig 4. Watson (2019) Uros, a recognized ancestral, indigenous and native town in Peru. p.277.

This knowledge of dealing with natural materials immerses the investigation on natural growth dynamics and inherent unpredictability. It embraces what Myers (2018, p.42) calls the 'aesthetic of uncertainty' that embraces material instability, impermanence, and self-sufficiency, as in the coastal fishing boat (Fig. 5).

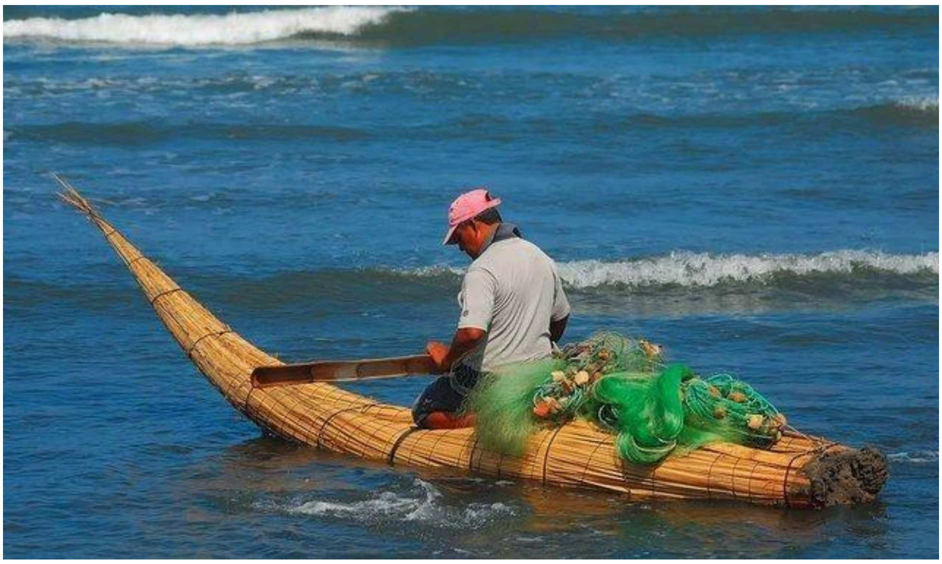

Fig 5. Erič (2016) A typical totora boat called caballito del totora or horse reed boat from the Trojiljo district on the northern Pacific coast of Peru. p.39.

Biodesign and the Koutammakou Silkien Houses - from Vitra Design Museum, 2013

Another project on the use of local construction materials and principles comes from Koutammakou, a vast region spanning northwestern Benin and northeastern Togo, Afrika. Primarily defined by the Atacora Mountains, this landscape is home to the Batammariba people, whose name in the Ditammari translates to "those who shape the earth."

Their distinctive mud tower-houses (Fig. 6), called sikien (with the singular form takienta), are made of traditional adobe or stone. Circular or elliptical forms characterize them and are usually gathered in units corresponding to family groups, often enclosed by earthen walls and sometimes interlinked.

Fig 6. Deidi van Schaewe (Vitra Design Museum) (2013) Taberma Tata or Takienta, Togo

Their unique architectural practices testify to their deep connection with the soil, an "expanded" Biomaterial considered a once-lived element. We can also see the relationship with the natural surroundings in Togo's pottery (Fig. 7). It illustrates how their community has continuously sought a balance between human life and the environment and how Nature influences beliefs, rituals, and daily life.

Fig 7. Yavo (2013) Ceramics pots inside of a canary, Togo. p.283.

Banana Leaf by Eames 1972 from BIO27 | Super Vernaculars, 2022

Banana Leaf is a 1:32-minute parable, photographed in live-action, by Ray and Charles Eames (1972). It was shown again in the BIO27 | Super Vernaculars, 2022, as an example of "a dish for eating from without a designer's intervention" (Fig. 8).

Fig 8. BIO27 | Super Vernaculars (2022) Banana Leaf shot screen. p.53.

South Asia is the world's largest producer of bananas (Musa spp.) due to its ideal climatic conditions. After the fruit is harvested, the leaves can be repurposed to create cost-effective packaging materials (Ezeudu et al., 2020). They are ideal for wrapping and steaming food (Fig. 9) because the leaves are large, flexible, naturally waterproof, and a source of antioxidants, which can help preserve packaged goods for longer (Sasikala & Umapathy, 2018).

Fig 9. Fitriani et al., (2017) Traditional "ombus ombus" food packaged using banana leaves. p. 19.

In an era of limited resources, simple and efficient natural materials can be a solution, especially when they reveal vernacular traditions and "values systems largely ignored in the modern era to create imaginative responses to contemporary challenges such as water scarcity, waste and declining biodiversity" (Super Vernaculars, 2022) resonating with Camere and Karana's Biodesign approach (2017).

Biodesign and the Amazonian Cuias - from What Design Can Do Conference at Mexico City (2023).

Cuias, crafted from the fruit of the Crescentia cujete tree, are made through an intricate process in which the fruit's skin is transformed into objects such as pots, bags, vases, and packaging. They exist in areas from México to Brazil (Moreira, 2017) and exhibit diverse production techniques.

Andrea Bandoni, when speaking at the What Design Can Do Conference in Mexico City (2023), showed a "cuia-de-gomos" from the 18th century (Fig. 10). This piece is an ancient craft pot-shaped utilizing a string and a wooden base around the growing fruit, resulting in an unnatural form. The riverside artisans do not use this traditional technique nowadays; their pots (Fig. 11) still resemble contemporary Biodesign practices when manipulating the natural material (Karana & Camere, 2017). However, their form is similar to when the fruit is harvested, using only one-color sample and fewer symbols engraved.

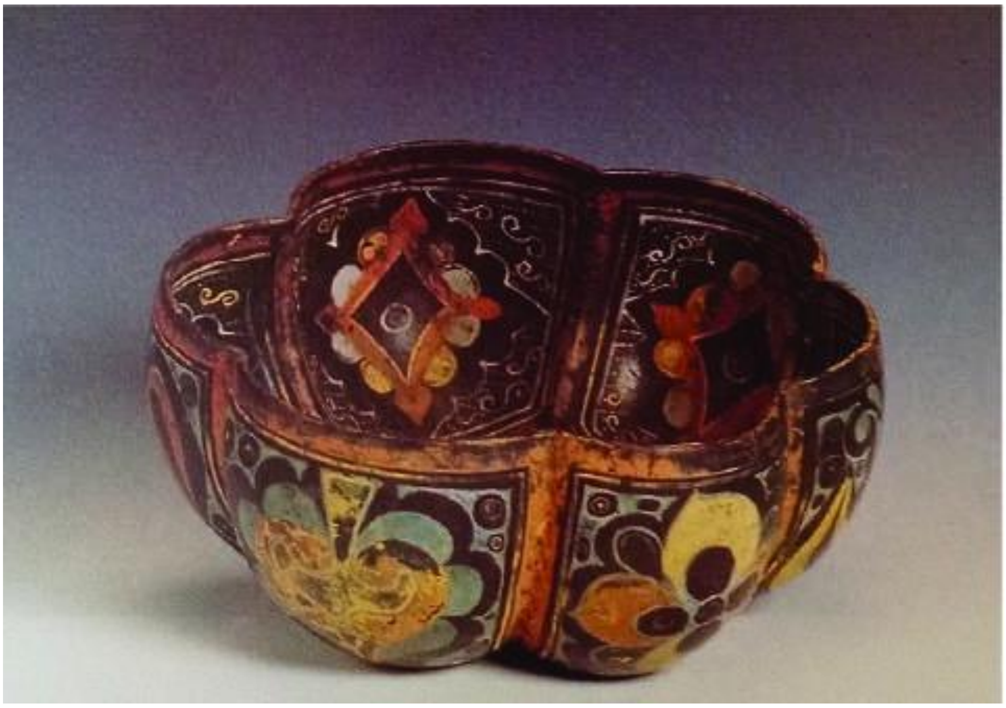

Fig 10. Hartmann (1991) "Cuia-de-gomos" – a fruit molded and transformed into object by Amazonians in the 18th century. (Part of the collection of the Museum Maynense at Lisbon Science Academy)

Fig 11. Bandoni et al. (2023) Contemporary cuias from the Association of Riverine Artisans of Santarém (Asarisan)

Analysis

Examining the abovementioned study cases, it becomes evident that Ancestral Practices exhibit striking parallels with contemporary Biodesign approaches. For instance, all the examples used organic materials and objects correlated with local environmental conditions, deeply rooted in place. Verification happened through repetition; they embraced the complexity and diversity of the practices. The makers understood and respected Earth systems' cycles, connections and changes. They also presented a close relationship with sustainability pillars, encapsulating ecological, social and economic values regarding resource efficiency.

The research and analyses of traditional case studies could persist. The problem would continue to be the dilemma of labeling the Ancient Practices found. That is because there are differences, as seen in the following table.

Table 1 – Differences between Ancestral Knowledge and Traditional Practices & Biodesign (adapted from Chapin et al. (2013)

Ancestral Knowledge and Traditional Practices	Biodesign
Qualitative oral record Communication of stories connected to life and values Local verification Practical and body-centred experimentation Trust in inherited wisdom Emphasis on skills and knowledge application Holistic Intergenerational methods of knowledge	Qualitative and quantitative written record communication of procedures, evidence and theory Local and global verification Controlled experimentation Scepticism Emphasis on understanding mechanisms part to whole Scientific knowledge

The cases underscore the tension between recognizing the importance of traditional knowledge systems and perpetuating colonialist viewpoints. Biodesign may recognize the ingenuity of traditional practices, but it risks ignoring their origins and homogenizing their knowledge. It aligns with a Eurocentric perspective, which mainly does not recognize ancestral know-how, nor does it give importance to preserving and perpetuating Indigenous or Ancestral wisdom.

They also confront the challenge of scalability and non-standardization that natural materials variability presents. Ancestral Knowledge and Traditional Practices use a subsistence strategy, with a production that remains correlated to the local society's needs. Biodesign, sometimes, is more concerned with industrial and global-scale production.

However, our research question - Can an ancient practice, predating and existing outside the scientific framework, be classified as "Biodesign?" -has yet to be answered. Authors Ginsberg and Chieza (2018) argued that despite Biodesign's contemporary appearance, its foundational principles are deeply rooted in traditional practices such as organism refinement through selective processes reminiscent of age-old agricultural and vernacular architectural techniques.

Similarly, Hénaff (2023) emphasizes the historical influence of earlier societies, suggesting that they have historically used their understanding of biological organisms and systems to address diverse hierarchies of needs long before Western scientists. Hénaff's perspective calls for a critical reevaluation of the prevailing Western-centric definition of biotechnology and design, urging researchers to identify and bridge the gaps in mainstream conceptualizations.

Defining ancient practices using current nomenclature may highlight the relevance of ancient wisdom in modern society but risks erasing the deeper meanings and understandings behind these practices, thereby diminishing cultural diversity and complexity. As Paulo Freire (1987) aptly noted, language can be a tool of domination, and it is imperative to be cognizant of this when seeking alternatives to prevailing crises.

Alternatively, as explained by Nêgo Bispo (Santos, 2023) in his "war of denominations" or "the game of countering colonial words as a way of weakening them," he replaces sustainable development with bio-interaction, coincidence with confluence, synthetic knowledge with organic knowledge, transport with transfluence, exchange with sharing, politics with self-management, and the dream with the imagination. He would suggest being careful with the chosen worlds in this paper.

Conclusion

This article explores the parallels between Ancient Practices and contemporary methodologies, particularly in Biodesign and Urbanism. It underscores the challenges of applying Western terminology to traditional practices and reiterates the crucial importance of recognizing Indigenous and Ancient Knowledge systems.

In light of these considerations, and following the example of "tropical urbanism," it advocates for utilizing the term "Biodesign" alongside qualifiers such as "Ancestral," "Vernacular," "Indigenous," "Traditional," or even "Biocraft" to acknowledge this heritage while avoiding colonialist perspectives. Meanwhile, it suggests a more inclusive and decolonized approach to understanding and naming ancient practices.

This approach delineates Ancient Biodesign practices from their contemporary counterparts while acknowledging their relationship with traditional and natural practices. By incorporating decolonial perspectives, practitioners can ensure that these approaches are distinguished and that their custodians receive due recognition and credit for their contributions.

It's important to note that this is just the beginning of a lengthy investigation and that more case studies should be included in future research. This study did not fully address the dynamic challenge of scientific inquiry and creative disciplines when considering how meaningful collaboration can be fostered with ancestral people. "What mechanisms can co-produce knowledge collaboratively, ensuring equitable participation and outcomes for all stakeholders? " could be the following research question. It underscores the ongoing nature of the research and the need for further investigation.

As this investigation exemplifies, the juxtaposition of Ancient Practices with contemporary analogies underscores the imperative of acknowledging Ancestral and Indigenous society's historical legacies, cultural rights, and concerns—recognizing them as the original creative actors—in ongoing discourse. While the convergence of traditional technologies with modern knowledge holds promise for fostering innovative approaches to resource management, biodiversity conservation, and sustainable actions, it necessitates a balanced and mutually beneficial engagement between all parties involved.

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Sustainable Craft Futures
Mapping Pathways for Regeneration through Natural Fibres

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Keywords: Regenerative economies, natural fibres, social innovators, India's handmade sector, wild grasses, bamboo, banana fibre

Introduction

In response to the imperative of developing non-toxic and non-exploitative creative processes, this paper explores how an array of social enterprises and innovators in India are systematically engaging with natural materials to foster social, economic and ecological regeneration. By integrating novel designs with traditional techniques, a model that respects both the carrying capacity of bio-regions and the cultural heritage of local communities has emerged.

Natural fibres serve as a crucial resource base for the handmade industry. With a diverse array of grass, banana and bamboo species forming a significant portion of India's forest and land cover, they represent vital assets for sustainable development. This paper examines the potential of these carbon- mitigating resources in advancing creative economies, given their local availability, renewability and low-input requirements.

As a researcher and curator working on convergence of crafts with climate action, this paper reflects strategies and directions that support the belief that a matrix of localism, an inclusive approach and investment can enhance the global adoption of low-impact materials like natural fibres. Traditional items of everyday use made from natural fibres are perennially in demand locally and sold in local bi- weekly haats or markets in Indian villages. They continue to fulfil local production-to-consumption (P2C), a system foundationally disrupted in the post-industrial era. However, the producers—mostly part-time craft makers and seasonal agriculturalists—remain on the periphery of development initiatives, perpetuating generational poverty. This situation is further exacerbated by climate change, which disproportionately heightens vulnerabilities and risks for the most marginalized groups, including smallholder farmers, women, and indigenous communities (Bhargava & Bhargava, World Economic Forum, 2023).

Against this background social innovation plays a pivotal role in solving complex problems in rural economies, promoting inclusive leadership values and advancing sustainable and fair solutions that also align with European markets. The paper attempts at establishing that systems thinking is critical to design inclusive growth models, adopted by the profiled enterprises—namely, Kadam Haat, The Kishkinda Trust, and Industree. The value chain credentials of natural fibres within these social enterprises-at farm to finished product stage—regenerative agriculture, soil health, science of dyes and waste management—establish them as materials conscious of their full creative cycle. Contemporary and utilitarian products made from such materials comprise tote bags, lunch bags, wallets, laptop sleeves, jewellery boxes, bamboo trays, storage organisers and more.

The concept of 'regeneration' has been understood as a multidisciplinary living systems principle that extends beyond the domain of agriculture, with social enterprises acting as catalysts of regenerative economies. Instead of developing novel materials, resources synchronous with ecological rhythm are highlighted for their potential revival and deserving of supply chain investment. Business models of the three enterprises inform frameworks, blueprints and catalytic capital models to advance creative industries in the global south. A recent study, the Financing the Handmade report, highlights that inclusive growth, centred on people and planet welfare, is a key driver for craft-led MSMEs (Micro, Small & Medium Enterprises, a ministry under the Government of India). The report surveyed 516 handmade, craft-led MSMEs and found that brand building/profit (89%), community well-being (72%) and environmental sustainability (33%) are their top three desired goals (200 Million Artisans, 2023, p. 15).

Making design an integral part of this narrative through material optimisation, its stock-flow opportunities, biodegradability and social impact potential can unlock creative options in line with the 1.5-degree pathway by achieving multiple Sustainable Development Goals (SDGs). Carbon market potential for natural fibres is also a promising development opportunity, though research methodologies for calculation and trading need to be developed.

Methodology

"From an environmental point of view, a broom is a sustainable product. It occurs naturally in the wild, it is harvested seasonally in a manner that does not harm the soil or the environment. Its life cycle is beautifully circular and complete. It has a natural birth, it lives a full, useful life, and it dies a helpful death as fodder for cattle, only to return the following monsoon as new life. Its life is lived lightly on earth. Born from nature, transformed by human hands, and woven into the social and cultural fabric of civilization, it then dies in the arms of nature, to be reborn from the earth once again"

– Ela R. Bhatt, Anubandh: Building Hundred Mile Communities, 2015, p. 3

A humble grass broom, commonly found in Indian households, is used daily to clear dust, reflecting a ritual of renewal. Ela R. Bhatt, the late Gandhian and founder of SEWA, cited it as a simple yet profound example of regeneration. This unassuming tool, though low in economic value, plays a crucial role in sustaining life and economic activity by continually renewing living systems.

The premise of this paper will explore this regenerative analogy in a dual manner: one focusing on the potential of natural fibres at the material level, and the other at the structural level, elucidating the role of social entrepreneurship in shaping pathways for inclusive growth. A key hypothesis is that as industries worldwide are actioning a transition from linear to circular models, craft ecosystems possess inherent mechanisms to achieve sustainable objectives.

The methodology comprises the application of academic, primary and secondary research. In this context, academic refers to the broad application of key learnings I gathered as a student of the last cohort of 'Regenerative Economies', Harvard Extension School.

The natural fibre ecosystem will be studied through assessment of the entrepreneurial portfolio of three craft-led MSMEs (Micro, Small & Medium Enterprises, a ministry under Government of India) in India: Industree, Kadam Haat and The Kishkinda Trust. The reason for selecting these three enterprises is their proven track record in successful community mobilisation and large-scale product development using natural fibres for the contemporary global market. This paper utilises primary research through virtual as well as physical interviews with the founders and visits to a few clusters to examine the business models, material evolution and social impact. Additionally, secondary research includes a. seminal craft documentation resources for mapping resource base, b. latest industry white papers for data and growth potential and c. contextualisation of the work of educators in regenerative disciplines.

Framework Development for a Regenerative Ecosystem using Natural Fibres

Regenerative practices in fashion and design draw from regenerative agriculture, popularized in the 1980s by the Rodale Institute. This approach, aimed at improving soil health and ecosystem resilience, has been uniquely interpreted by institutions like Harvard Extension School and Schumacher College to transform value chains and knowledge systems. Carol Sanford, author of *The Regenerative Business and The Regenerative Life*, developed frameworks based on living systems thinking to create enduring wealth. This perspective aligns with the vision and progression of three social enterprises discussed in this paper, which Sanford would consider as 'economic shapers' (Sanford, 2021, p. 127). This section 'Framework Development for a Regenerative Ecosystem using Natural Fibres' adopts an enterprise-focussed approach to analyse the vision and framework necessary to transform a dormant resource into an asset and ultimately into a viable and scalable business model. Sanford emphasizes that one of the critical tools used by economic shapers is discourse, which helps create widespread impact (Sanford, 2021, p. 127). Discourse formation can be interpreted as the organisation's vision, blueprint or north star, a crucial element that guides operation, impact as well as investment.

Social Enterprise 1 - Industree Foundation: The 6C Framework and Hybrid Capital

Neelam Chhiber, 59, is a trailblazing figure in India's creative manufacturing sector. A designer by education from the National Institute of Design (NID), Ahmedabad, one of the leading design schools in India, she has just retired as co-founder and managing trustee of three-decades-old Industree Foundation, Industree Skills and Mother Earth based out of Bengaluru, India.

Neelam recognised early in her career the deep disconnect that had emerged post-industrialization between anonymous rural artisans in India, their eco-friendly products and a market increasingly dominated by modern, industrial goods. According to Chatterjee (2019, p. 203), witnessing the transformational shifts in economic, social and political contexts across the world also led the Indian government to label crafts as a "sunset industry," seen as incapable of driving economic growth. Against this backdrop, Industree's business model was born in 2000, focused on empowering non- farm producers from remote regions of India, with an ambition to organise the decentralised sector. Over the following decades, as revealed by Neelam in primary interviews, Industree successfully implemented a 6C framework—Create, Construct, Capital, Capacity, Channel, and Connect—that effectively drives transformation and attracts resources within ecosystems. This framework, grounded in the principles of a place-based economy, successfully incubates and develops producer cooperatives. The model utilizes high carbon-sequestration plants, such as bamboo and tree waste, including sal leaves and banana bark, to create sustainable products.

The components of the 6Cs work together to create a holistic value chain. We can explore the agro-to- craft banana bark value chain across four clusters in Tamil Nadu, the southernmost state in India and one of the largest domestic producers of bananas. Locally available materials are identified (Create), producer groups are mobilized (Connect), and infrastructure is developed to meet international standards (Construct). Additionally, capacity building in both hard and soft skills ensures the production of high-quality products. R&D, design development and product development are all parts of 'Create'. GreenKraft, 100% women-producer-owned enterprise manufacturing hand-woven products made from waste banana bark is an example of the successful application of this model (Fig 1).

Fig 1. Industree (no date) Scene on site at GreenKraft, Tamil Nadu manufacturing hand-woven products made from waste banana bark.

Few organisations in craft-led MSMEs have been able to successfully follow a 'hybrid' economic model meaning, two distinct legal entities: a for-profit and a nonprofit that operate in parallel. By keeping an arm's distance, this model effectively addresses, legitimises as well as operationalises commercial and impact goals. The 'Capital' component is crucial, securing various funding levels to enable producer companies to grow, become profitable, and self-sustain. Both Industree Foundation and Kadam Haat (second enterprise of this study) follow this capital machinery, making hybrid capital a powerful tool for sustainable economic development in rural communities.

Social Enterprise 2 - Kadam Haat: Redefining Circularity

Kadam Haat operates as a hybrid model, with Kadam, a not-for-profit organization founded in 2006, and Kadam Haat, a social enterprise launched in 2008 to market the products created by Kadam. This circular approach uses hybrid machinery to optimize funding and reinvestment in community mobilization, skills development, supply chain creation, governance, and market access, eventually transforming villages into entrepreneurial hubs. The blended capital model also serves as a buffer, such as through the creation of a material bank by Kadam to ensure a steady supply of wild grasses harvested seasonally from common village lands.

Circularity at Kadam Haat is achieved through relationship-building across social factions and genders, fostering community engagement and teamwork. Women make up 85% of the workforce, working alongside men (15%), ensuring equitable participation even in conservative societies (Fig 2). This collaborative approach extends across social groups, such as metalsmiths crafting basket frames and women coiling fibres, resulting in a critical social exchange. This collective, community- oriented production defines Kadam Haat's circular model.

Fig 2. Kadam Haat (no date) Natural Fibre artisan group.

Social Enterprise 3 - The Kishkinda Trust: Rural Development in a Heritage Setting

In 1998, Shama Pawar, founder of The Kishkinda Trust (TKT) established a banana fibre craft initiative in the historic settlement of Anegundi near a UNESCO world heritage site, Hampi in Karnataka (Fig 3). It was the original capital of the Vijayanagara Empire, dating back to the 14th century and earlier. Anegundi means the elephant pit in Kannada and it is believed that the royal elephants were bathed here.

Fig 3. Arial image of Anegundi village situated on the northern bank of river Tungabhadra, Karnataka.

A proponent of the potential of cultural industries and creative economies, Shama refers to her holistic model as 'Rural Development in a Heritage Setting.' The potential of cultural and creative industries leveraging creativity for territorial transformation, economic recognition and value creation in areas with UNESCO world heritage sites has been widely discussed since 1970s (Schröder et al., 2022, p. 55). The Kishkinda Trust can be understood as the activation of a dense and dynamic network of spatially bound factors–self-sufficient village economies, agriculture/horticulture, architecture, local skills, conservation, soil, cultural landscape and experience-in short, both tangible and intangible resources. A circular-design approach to assets can be observed in Anegundi today through the work of TKT, be it the refurbishment of neglected heritage via the architectural conservation of traditional vernacular houses, the revival of folk traditions or the promotion of responsible tourism.

Role of Bio-materials and Design in Driving Circular Economies

Traveling through the hinterlands and countryside of India reveals a diverse and ecologically significant landscape. Regions such as Uttar Pradesh in the north, Bihar and West Bengal in the east, Karnataka and Kerala in the south, and Assam and Manipur in the northeast, exhibit a variety of flora including wild grasses, banana groves, palm trees and bamboo plantations. These vegetative areas often adjoin barren lands, agricultural fields and wetlands (Fig 4).

Fig 4. Moonj grass growing on the edge of agricultural land in Hardoi district, Uttar Pradesh.

A variety of plant fibres such as banana, pineapple, sisal, hemp, coconut, palm, grasses, ramie, palm, cotton, nettle etc. are grown since olden times in different parts of the world. These fibres can be extracted from different parts of the plant such as the bark (banana, jute, hemp, ramie), stem (banana, palm, bamboo), leaf (palm, screw pine, sisal, agave), husk (coir), seeds (cotton), and grass (sikki, moonj). India is known for its natural fibre crafts worldwide. Each craft uses different types of grasses grown in different states (Natural Fibres, Craftmark, p. 2).

Fig 5. Toddy farmer making boat-like container (doppa) from Palm tree in Nalgonda, Telangana.

Region's micro-climate, material's sturdiness and pliability and human skills have also shaped creative solutions. Bamboo rain sheds of Assam, Tripura and Meghalaya are worn by farmers as headgear while fresh palm leaf is moulded into a boat-like container (doppa) for drinking toddy or palm wine extracted from the trees in Telangana (Fig 5). The bamboo rain shed hat, locally called jhappi, is adorned with red appliqued forms and transformed into a votive offering symbolizing a good harvest (Fig 6). These responses exemplify the resilience and ingenuity of the human spirit in harmonizing with nature.

Fig 6. Rituparno Dutta (no date) Jhappi, bamboo hat from Assam decorated with red appliqued forms.

This also reflects indigenous systems that inherently focus on closing the loop by designing out waste, maximizing resource use and aligning consumption with a deep-seated respect for nature. Social innovators are tapping system thinking to bring overlooked waste and latent materials to the forefront, emerging as sustainable alternatives to the synthetic materials that gained excessive favour after industrialization.

A. Banana Bark and Fibre

Industree: Banana bark, an agricultural byproduct generated after the harvesting of the fruit in the Indian states of Tamil Nadu, Karnataka, Andhra Pradesh etc. is typically disposed of through burning or landfilling, contributing to greenhouse gas emissions (GHGs). As a core component of 'Create' within Industree, R&D activities are conducted in laboratories to establish new product lines to utilise underutilised resources. Through backward integration, the organisation directly procures the banana bark from farmers and incorporates it into the production of basketry and handloom products. The bark is also twisted into ropes and used to craft a variety of woven products (Fig 7). Within the enterprise's training programs, eco-friendly items such as handcrafted home décor and storage solutions are developed. The development process involves product construction through lean manufacturing techniques – a combination of hand and machine and applying industrial design principles to enhance product quality and productivity.

Fig 7. Industree (no date) Woman artisan working with banana bark to make baskets.

The Kishkinda Trust: In terms of material identification, innovation and generating new value-creation loops, The Kishkinda Trust has created an immense impact with the banana fibre value chain. "Hampi has almost 1,000 women or 800 women who are doing banana fibre other than Kishkinda Trust. We created something, and a lot of people have taken to it, which is a compliment", says Shama in a virtual interview. Banana fibre, originally agro-waste, was introduced as a craft in Anegundi by The Kishkinda Trust (TKT), engaging first- and second-generation women in the region. TKT recognized the potential of the banana tree trunk and added value to it for contemporary products like handbags, storage bins, and rugs, available on TKT's website and through ethical retailers like Powered by People. The first step was educating local farmers, assuring them that harvesting the dry trunk wouldn't harm the standing crop. Only the dried trunks are purchased, then dried, hand-twisted into ropes, and crafted into products—an entirely manual and costly process (Fig 8). Most product design and material R&D are done in-house, with lean machinery in development to improve cost efficiency and scalability. "It started because I didn't want my son to carry a plastic tiffin bag," says Shama, recalling the first banana fibre tiffin bag made in 1999. The products retain their natural beige colour without dyes.

B. Bamboo

Understanding innovation in bamboo requires examining the supportive domestic environment that benefits producers and craft-led MSMEs. The National Bamboo Mission (NBM), a Government of India initiative, emphasizes the holistic development of the bamboo sector, integrating both farming and product development. Despite bamboo's long-standing use in crafts like furniture, basketry, and housing, significant gaps exist in embedding bamboo into modern economic frameworks.

Fig 8. The Kishkinda Trust (no date) Women of Hari Dharti Rural Development Society (HDRDS), a producer cooperative instituted by The Kishkinda Trust working with Banana fibre.

Industree Foundation's 2020 initiative, POWER (Producer-Owned Women Enterprises), addresses these gaps through a climate-resilient, women-led project in Karnataka and Maharashtra. Supported by NBM and USAID, the project encourages marginal farm families to plant bamboo, enhancing their income while contributing to biosphere regeneration via permaculture practices. These efforts aim to establish India's first Forest Stewardship Council (FSC) certified bamboo plantations.

A key advancement is the establishment of the Bamboo Research Centre in Channapatna, Karnataka, functioning as a business and livelihood incubator. This centre facilitates the formation of collectives, providing end-to-end support from bamboo plantation to the global market. Additionally, Industree's Platform for Inclusive Entrepreneurship (PIE) is developing bamboo farm-to-product manuals as a collective common resource to fill the knowledge gap for aspiring farmers and producers, actioning the ethos of mutualism and generosity which are foundational to a regenerative practice.

The initiative reconnects indigenous communities with their traditional crafts through social innovation, supporting the socio-economic development of the Medhar community in Karnataka (Fig 9). This community, historically integral to the bamboo value chain due to their skills and techniques since 1200 AD, has faced challenges in gaining social and economic benefits due to a lack of resourceful initiatives. By recognising the inherent intelligence at all levels and reinforcing self- organization, Industree ensures that innovation can emerge organically, addressing the socio- economic gaps and promoting sustainable development within these communities.

Fig 9. Industree (no date) Bamboo plantations by small-land holding farmers part of Industree’s POWER initiative.

C. Grasses (both wild and cultivated)

According to Payal Nath, co-founder of Kadam Haat (KH), India is home to 10 of the 12 global sub- species of grasses, and Kadam Haat works with nine of them, including bamboo. These grasses are regionally distributed: in West Bengal, artisans use sabai grass, sitalpati, madhur kathi, and shola pith; in Odisha, golden grass and sabai; in Uttar Pradesh, kansa and moonj grasses; in Kashmir, willow wicker; and in Bihar, sikki grass.

Payal Nath recalls that when she started her entrepreneurial venture two decades ago, she consciously chose to work with the most marginalized communities and overlooked materials. “Even now, the skill levels in communities working with natural fibres are not particularly strong. Traditional methods are often outdated, taking significant time without yielding proportional value. We break these barriers to make the craft relevant for today.” Kadam Haat has honed what it calls "process engineering" in natural fibres—breaking down processes to achieve optimal forms, sturdiness and functionality. Design and product development are ongoing, with approximately 600 designs created so far, 150 of which were featured on Kadam Haat’s website last financial year.

One example is Kadam Haat's bestselling sitalpati laptop sleeve, which showcases transformation design thinking at both the design and dye stages. Sitalpati, meaning ‘cool mat’ in Bengali, is traditionally made from locally grown reed in Cooch Behar, West Bengal. Known for its cooling effect and silken texture, achieved through the seamless plaiting of thin reed strips in a twill pattern, sitalpati mats are a craft of the Kayastha community, who cut the reeds using traditional tools.

Leveraged this traditional skill to create products involves resource mapping followed by building relationships with artisans, defining modern product requirements, adapting traditional techniques and iterating designs. The resulting laptop sleeve (Fig 10) features minimal aesthetics, sleek design, padding for cushioning and reed that complements temperature control—ideal for laptops. In a pioneering move, after much iteration two REACH-certified dyes (Registration, Evaluation, Authorization and Restriction of Chemicals) in black and blue have been perfected to deliver monochromatic and matte shades appealing to a cosmopolitan and conscious audience. The product is 100% eco-friendly and compostable, embodying the 'soil-to-soil' regenerative principle.

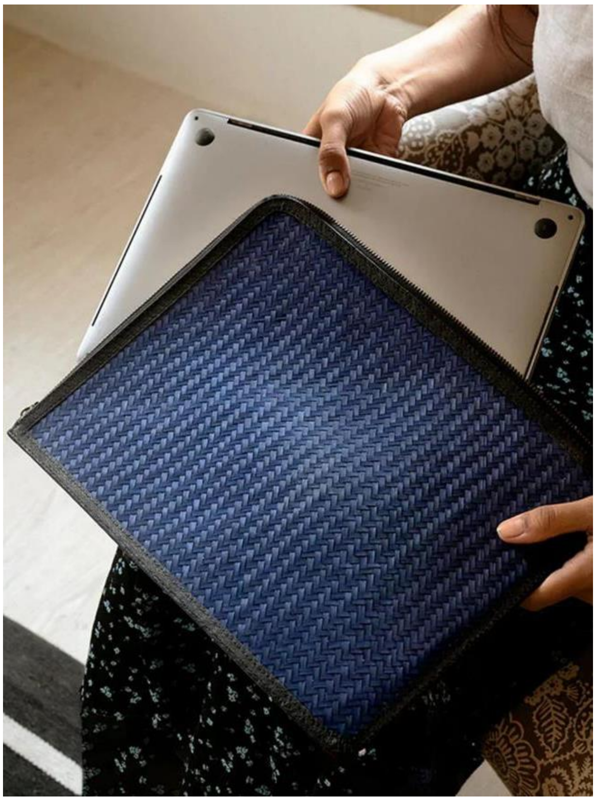

Fig 10. Kadam Haat (no date) Kadam Haat’s Sitalpati Laptop Sleeve.

Potential of Carbon Market

Carbon markets have emerged as an alternative source of mobilising resources for mitigating climate change. Within the handicraft sector, especially with natural fibres it can unlock new revenue streams for ethical grassroot producers plus contribute to global climate mitigation efforts. An extremely low- carbon production from farm to final product is a viable base for exploring the carbon market.

The materials in the value-chain discussed emphasis regenerative way of material cultivation, in both organised and unorganised ways. For example, while bamboo agriculture is moving towards cultivation in forest stewardship mechanisms, wild grasses grow in unattended land parcels, typically classified as 'wastelands.' However, these lands serve as village common lands and are recognized as potent carbon sinks within global environmental discourse. They grow in the wild requiring no fertiliser or planned irrigation system. These areas play a critical role in maintaining ecological balance and sequestering carbon through extensive root systems, which store carbon in the soil. Depending on the grass species significant amounts of carbon both above and below ground can be sequestered. Above ground, the biomass of wild grasses captures atmospheric carbon dioxide through photosynthesis, contributing to carbon sequestration. The extraction system employed by communities adheres to a no-tillage approach, preserving the root system, allowing the grasses to regenerate and maintain soil health, further enhancing their role in carbon sequestration and promoting ecological sustainability. Wild grasses can sequester up to 3 tons of carbon per hectare per year, depending on the species and environmental conditions (Bai, Y., & Cotrufo, M. F., 2022, p. 1058-1065). They can be an essential component in strategies promoting sustainable land management practices.

In India, the carbon credit market against banana fibre or wild grasses has not been explored as extensive funding for feasibility assessment as well as methodology creation against existing life cycle will be developed. In recent development, Varaha India, a decarbonization tech venture is exploring the carbon market through a project in Africa. The project is in inception stage, whose details are not out in public. If the pilot of successful, organisations with scalability can develop feasibility plans.

Bamboo also has impressive carbon sequestration credentials. On average, one hectare of bamboo can absorb approximately 17 metric tons of carbon dioxide per year. Industree has planted ~1,575 hectares of bamboo, sequestering ~26K tons of CO_2 annually (Industree Annual Report, 2023, p. 9). These carbon offsets created through Industree's initiatives could potentially be monetized in the carbon market.

From Industrial Scaling to Ecological and Social Integration

In the 1990s, basketry in Moradabad, Uttar Pradesh, was industrialized, with raw materials transported to factories where production occurred in detached, ecologically indifferent environments—a hallmark of industrial progress. By challenging these conventional frameworks, social innovators and economic shapers such as Kadam Haat, Industree, and The Kishkinda Trust have pioneered a paradigm shift that integrates ecological and social dimensions into production. Their regenerative systems leverage heterogeneous, distributed biomass, creating a ripple effect that benefits even the most remote producers. This new approach signifies a revolutionary shift in how we can view the future of natural fibres, transforming traditional products like mats, stools, and baskets from local to refined domestic and global markets. A key takeaway is the transition from vertical industrial scaling to a model of horizontal collectivization, which fosters socially responsible growth and redefines sustainable development pathways.

Benchmarks for International Market

Besides developing alternate ecosystems that can compete with industrial quality designs, the profiled organisations have played a crucial role in establishing benchmarking systems within the handicrafts sector that address multiple SDGs and have global applications. We have understood that Industree's 6C framework can serve as a comprehensive tool for enterprise building. Additionally, Industree has an emergent Equity, Climate and Gender (ECG) framework, tailored to the Global South, that has impacted 500,000 lives and facilitated over $58 million in market access, nurturing climate-positive local economies. The framework is adaptive and not evaluative in intent, allowing organizations to follow distinctive courses and is being offered to social innovators globally including the Catalyst 2030 (a global movement of social entrepreneurs with the common goal of creating innovative, people-centric approaches to attain the SDGs by 2030).

Organising and scaling resources at the bottom-up level for a compliant global value chain is Industree's vital contribution to India's decentralized crafts ecosystem. The company's bamboo and banana fibre products have regular markets with major global brands like IKEA, West Elm, H&M, Carrefour, Anthropologie etc. and funding for projects from World Bank Institute, Commonwealth Secretariat, UNDP, US Aid etc. (Fig 11). Through GreenKraft, Industree has collectivized nearly 4,000 women producers and farmers in Tamil Nadu, forming a scalable, compliant and traceable enterprise that significantly reduces its carbon footprint. Example, by localising economic activities, it has saved 247,860 kilograms of CO_2 per year.

Fig 11. Industree (no date) Banana bark basketry for contemporary use.

With materials like grass, communities either restrict to natural shades of grass or dye them with bright market-available colours like pink, green, and red. The larger colour palette in natural fibre space relies on azo-free and chemical dyes, which can cut through the silica present in the wild grasses. However, for compliance and consumer trust, especially in the EU market, REACH-certified dyes are crucial. Forerunners like Kadam Haat, who are constantly investing in R&D through dedicated dyeing labs can eventually contribute to formalising better practices and bringing systematic changes within the decentralised crafts sector, addressing environmental challenges as production scales up.

Indicators of Prosperity

Regenerative economic models enhance human potential by focusing on the possibilities inherent in human agency (Sanford 2021, p. 129). At the rural level, handicraft production not only mitigates rural-to-urban migration but also provides productive employment opportunities. For examples, as the profits are distributed among the entire team, rather than individual artisans, the collective approach enables artisans to invest in community projects, such as libraries or solar lamps, thus intertwining social empowerment with economic empowerment. For example, in the small village of Hardoi, Uttar Pradesh, 149 first-generation women artisans engaged in moonj basketry have experienced a profound sense of financial independence and empowerment, gaining a sense of agency and purpose previously unfamiliar to them. Similarly, market for roti (bread) box crafted by the Sabai cluster in Odisha has transformed lives, including that of 40-year-old Nirupama Jena, a mother of two who now leads the enterprise.

Production for Kadam Haat occurs in artisans' homes rather than factories, allowing women to work in a safe environment, surrounded by children and peers, after completing daily chores. This setup enables group work and training within their own spaces (Fig 12). Over the past decade, Kadam Haat has engaged 1,100 artisans directly, impacting approximately 5,000 in total.

Similarly, the Kishkinda Trust's transition from direct involvement to an ecosystem enabler emphasizes research, technology and incubation of new materials. The Hari Dharti Rural Development Society (HDRDS), a cooperative of 750 women, has gained full ownership and management, aiming for self-sufficiency and market expansion. This evolution reflects a shift towards fostering long-term sustainability and community empowerment.

Fig 12. Kadam Haat (no date) Community mapping and training exercise in Sabai cluster, West Bengal by Kadam Haat.

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