Pollini, Barbara

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Published in:
Research Directions: Biotechnology Design

DOI:
10.1017/btd.2024.11

Published: 28/10/2024

Document Version
Publisher's PDF, also known as Version of record

Research Directions: Biotechnology Design

www.cambridge.org/btd

From biodesigners to designers in lab: testing the nuances of an emerging profession through autoethnography

Barbara Pollini[1,2]

[1]Design Department Politecnico di Milano, Milano, Italy and [2]Design Department, Aalto University, School of Arts, Design and Architecture, Espoo, Finland

Impact Paper

Cite this article: Pollini B (2024). From biodesigners to designers in lab: testing the nuances of an emerging profession through autoethnography. *Research Directions: Biotechnology Design*. **2**, e20, 1–12. https://doi.org/10.1017/btd.2024.11

Received: 3 January 2024
Revised: 17 May 2024
Accepted: 28 May 2024

Keywords:
Biodesign; biodesigner; designer in lab; material design; biotinkering; autoethnography

Corresponding author:
Barbara Pollini; Email: barbara.pollini@aalto.fi

Abstract

Biodesign is emerging as a radical design approach with great potential for the ecological turn, finally endorsed by some first academic courses providing designers with hybrid skills to embrace scientific disciplines. However, the resulting professional figure, the biodesigner, still needs to be better defined in the academic and grey literature, also considering the different and multiple facets that working between design and science may entail. This study presents four case studies of research through design (RTD), addressed by the author as an autoethnographic form of inquiry to clarify the roles a biodesigner could assume, emphasising the differences in methods, tools and workplaces, which inevitably affect the Biodesign outcomes. The author analyses her role as a *biodesigner* and *designer in lab*, working in teams and environments requiring different degrees of interdisciplinarity. Far from adopting a speculative approach, the RTDs focus on sustainable Material Design and Biodesign solutions that might be feasible in the short run, aiming to test the designer's abilities in enriching scientific research and investigating the role and contribution designers can play in scientific contexts of different intensities. The study demonstrates the possibility of a reciprocal knowledge transfer between design and science, highlighting the potential of the *designerly way of knowing* in bringing innovation to the scientific field.

Introduction

As the discipline of Biodesign consolidates, a resulting professional figure emerges in parallel, characterised by an orientation towards experimentation, sustainable innovation and a hybrid background that combines design and science. Biodesign is closely linked to the bottom-up phenomenon of science democratisation, involving designers eager to better understand scientific principles to apply nature's potential to design (Myers, 2012). Here, the figure of the biodesigner takes shape, still lacking a shared and established framework for definitions, tools and methodologies (Vijayakumar et al., 2024), to all intents and purposes hybrid. The following paragraphs will give an overview of the varied world of DIYbio practitioners, further focusing on the emergent figure of the biodesigner, who already appears to be evolving despite the discipline's young age. By adopting an autoethnographic method, the study delves into the figure of the *biodesigner* along with that of the *designer in lab* (an even more hybrid counterpart), thus reflecting on the different transdisciplinary nuances this profession can take, depending on the circumstances and the project's nature.

The multiple nuances of DIYbio practitioners

Biodesign is recognised as a discipline that intersects design and scientific knowledge, established as part of the DIY-Bio movement, and further developed under the influence of other emerging phenomena, such as do-it-yourself, citizen science, and hacking practices spanning from computers and software to genes (Myers, 2012; Seyfried et al., 2014; Elsacker et al., 2020; Keulartz and Belt, 2016). Therefore, Biodesign is part of that *fringe biotechnology* (Vaage, 2017) panorama inhabited by different practitioners with hybrid skills, approaches and goals. To comprehensively represent them, we can list (i) biohackers, (ii) scientists with a strong creative aptitude, (iii) bioartists, and (iv) biodesigners. These definitions frame slightly different profiles, which intertwine and influence each other, supporting creativity and innovation in design, art and science (Figure 1).

Biohackers

The DIY-biology movement promotes open access to scientific resources, such as modern molecular biology or synthetic biology. It promises to provide cheaper and low-tech solutions for social and environmental issues, such as biomonitoring, personal diagnostics and

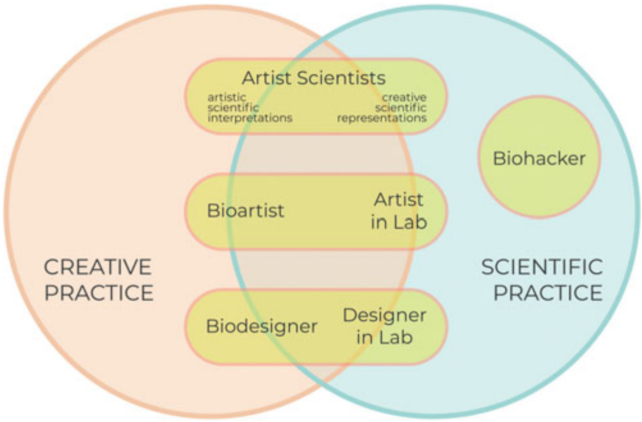

Figure 1. Positioning of the different professionals and approaches discussed across creative and scientific practices.

biomaterials, encouraging collaborations between professional scientists and amateurs (Landrain et al., 2013). Biohackers, also defined as DIY-biologists, are individuals who conduct biological experiments outside the traditional scientific research environment.[1] They operate in unconventional labs, outside academic and industry environments, known as *biohacker* or *biomaker spaces*[2]: citizen-friendly autonomous spaces where people interested in biotechnologies can gather to experiment with biological matter (de Beer and Jain, 2018). Biohackers usually have a strong scientific background and are oriented towards open and community science. They use the methods of science, although their equipment may be home-built and less sophisticated (Delfanti, 2012). The act of "hacking" here defines the general practice of modifying biology to suit new purposes, usually for the best (Roth, 2021).

Scientists with a strong creative aptitude (artist scientists)

STEM disciplines widely explored visual arts for clearer and more engaging communication to make accessible representations of scientific work (Gewin, 2021). Historically, visual literacy has been an essential subject in learning and communicating science. Today, creative approaches are considered a key skill for fostering innovation in scientific research; for this reason, STEAM[3] educational paths promote the integration with multiple arts to foster students' creativity (Segarra et al., 2018; Aguilera and Ortiz-Revilla, 2021). Scientists with strong creative aptitudes can be defined as professionals trained in scientific disciplines who use artistic means to enrich their studies or for artistic expression. They can create illustrations or 3D models with a more practical approach aimed at scientific representations. They can also experiment more interpretively, obtaining artistic outcomes starting from tools and techniques from their field of study. An example can be Jacob L. Steenwyk,[4] whose work on software development for life sciences led him to experiment with algorithmic-driven art.

Bioartists

Bioart is an umbrella definition for artistic practices that use biology, living organisms and life processes as media or tools of expression; it includes a wide variety of works dealing with different levels of manipulation, from the macro to the micro level of life, using different biotechnologies, from physical manipulation to genetic engineering (Myers, 2015; Kallergi, 2008). Bioart can foster interdisciplinary initiatives focusing on philosophical, social and environmental issues (Yetisen et al., 2015). In the attempt to interpret cultural transformations, bioartists are moved by artistic expression, design innovation, and activism (Asgarali-Hoffman and Hamidi, 2021). As stated in the bioart manifesto by multifaceted artist Eduardo Kac,[5] bioartists can use living media both to express human concerns and to celebrate non-human organisms; moreover, his manifesto points out the ethical implications of bioart, stating that "all art materials have ethical implications, but they are most pressing when the media are alive."[6] Compared to established bioethics in scientific contexts, bioart does not yet have a consolidated framework. However, many bioartists address the topic, giving rise to a flourishing ethical discussion concerning their field of practice (Vaage, 2016). Scientific knowledge is often indispensable for bio-artworks' success; bioartists' scientific literacy can be self-taught or nurtured by collaborations with experts in scientific disciplines- usually supported by specific programmes, such as artist-in-lab projects (Reichle, 2009). When bio-artworks are exhibited in a contemporary art institute, such wetworks and living life forms requires particular conditions or arrangements from the hosting institute, which often needs to set the right spatial conditions and incorporate new routines and procedures in its standard practices (Kallergi, 2008).

Biodesigners

Biodesigners' professional background is most often in design; therefore, their methods are based on hands-on experimentation, iteration, optimisation, and a centrality to the user's needs (Myers, 2018). Such background is later combined with scientific knowledge, amateurishly nurtured to create a peculiar hybrid profile. Only recently, biodesigners can properly acquire their "title" through a degree in this emerging field, where they are trained to deal with science's methods, languages, tools and spaces. Some dedicated academic study paths have recently been established to train design students for a basic understanding of life sciences and lab skills[7]; this could lead to a more conscious and proactive approach to designers' use of biotechnologies, other than facilitate cross-disciplinary collaborations. Either self-taught or academically trained, biodesigners tend towards a greater understanding of scientific principles to apply Nature's potential to the project, being prone to work transdisciplinary (Myers, 2012). Among other figures in the fringe biotech landscape, biodesigners are more oriented towards practice-based approaches to find innovative material and process solutions, employing living organisms in sustainable design outcomes (Wightman and Pirone, 2019; Grushkin, 2021; Langella, 2021). If early biodesigners worked predominantly in kitchens/garages/studios with DIY setups, now that the first biodesign academic courses provide designers with hybrid skills, they can finally operate in lab settings and learn the basics to possibly work in scientific environments. The fermenting DIY-biology phase that started the Biodesign phenomenon has been normalised within these training paths; this can reinforce the emergence of a more specific biodesigner profile, that of the designer in lab, performing in scientific labs, with more specific tools and scientific approaches (Langella, 2019).

The figure of the biodesigner will be further investigated in the following paragraphs, as the aim of this study is to better describe this emerging professional figure - poorly covered by the literature but already evolving,despite the young age of the field. This study adopted autoethnography (Munro, 2011; Jones, 2013; Adams et al.,

https://doi.org/10.1017/btd.2024.11 Published online by Cambridge University Press

2017) and research through design activities (Frayling, 1993) across design and science to better define the figure of the *biodesigner* and the *designer in lab* from a first-person perspective (Varela and Shear, 1999; Tomico et al., 2012; Tomico et al., 2023).

The emerging discipline of the biodesigner

Design's interest in scientific disciplines comes from two driving factors. On the one hand, the growing awareness of the environmental crisis has led designers to reflect on the responsibilities of their role and to reimagine matter and processes for more sustainable production models (Collet Carol, 2013; Camere and Karana, 2018; Myers, 2018; Karana, Barati and Giaccardi, 2020; Oxman et al., 2020; Langella, 2021). On the other hand, the democratisation of science has provided designers with new tools of expression and the possibility of imagining radical and sustainable future production scenarios. Despite designers' fascination for science implementation in design processes, acquiring such hybrid skills is not trivial. Possibly also to overcome this issue, the origin of Biodesign is characterised by a strong speculative component, often relying on diegetic prototypes and storytelling for future scenarios (Myers, 2012). Speculative Design does not focus on problem-solving but aims to ask "carefully crafted questions" (Dunne and Raby, 2001) to better understand the present and envision alternative futures, thus "being a means of debate and exploration of the alluring promises and alarming perils of manipulating life" (Myers, 2018). The first Biodesign training programmes often encouraged designers to embrace a speculative approach (Ginsberg et al., 2017; Wightman and Pirone, 2019), associating Biodesign with anticipatory fiction and not describing it as a discipline capable of solving societal and environmental issues in the medium-short term; for some scholars, the allure of design with the living was enough to suspend the requirement for a practical design outcome (Figueroa and Carolina, 2018). Interdisciplinary collaborations between design and science may help overcome this misconception, validating the feasibility of Biodesign projects and supporting innovation and practical solutions with scientific knowledge and equipment. However, these collaborations do not yet take place regularly, although their intrinsic value to solve complex future challenges such as sustainability issues is recognised (Mejía et al., 2023). More recent dedicated Biodesign academic programs, nonetheless, support designers' scientific literacy by enhancing the effective adoption of biotechnologies and facilitating cross-disciplinary collaborations.

Despite Biodesign being increasingly recognised at an academic level, the novelty of the field still lacks an explicit pedagogy (Roshko, 2010; Vijayakumar et al., 2024; Wightman and Pirone, 2019; Walker and Kafai, 2021) and dedicated methodologies (Camere and Karana, 2018; Esat and Ahmed-Kristensen, 2018; Vijayakumar et al., 2024; Walker, 2021; Ferruzca et al., 2022). The very figure of the biodesigner today has an uncertain definition, addressed with slightly different terminologies: *biodesigner*, *bioneer*, or *designer in lab* are some definitions currently in use. *Biodesigner* is the most shared one, directly derived from the discipline. Even without a clear definition in the academic and grey literature, it appears to be the norm for this emerging professional figure to deal with interdisciplinary environments and work in hands-on experimental research paths (Langella, 2019; Wightman and Pirone, 2019). Daniel Grushkin (2021), founder and executive director of the Biodesign Challenge, describes the profile of biodesigners based on his direct experience. He points out that their design ideas are as plausible and exciting as they are rudimentary; moreover, biodesigners feel the burden of liability arising from ideas and technologies that may be misused. Among the recurring characteristics that he observed in biodesigners there is a general attention to sustainability issues (such as systems theory, the life cycle of materials and products and the circular economy), a focus on non-human users,a tendency towards multispecies design, a scepticism towards consumer culture and a general optimism – tending to believe that there are multiple ways (from technological to behavioural) to mitigate and reverse the consequences of climate change and environmental degradation (Grushkin, 2021). Taking biofabricated materials as an entry point, Camere and Karana (2018) reported a particular sensitivity of biodesigners towards the living agents involved in the design process, highlighting the importance of such design sensibilities to face complex interdisciplinary problems. Emma van der Leest has coined the variant *bioneers*[8] to highlight the pioneering work that designers, pushing their knowledge to other domains, could acquire through innovative solutions. Here, biodesigners are seen as trailblazers; indeed, the early practitioners in the field captured the spirit of an emerging phenomenon, sometimes contributing to the movement as researchers and entrepreneurs of new biotechnological solutions.[9] The concept of *designer in lab* describes those designers who conduct activities in scientific laboratories and no longer in the design studio only; such designers are keen to apply scientific methods, embracing the rigour of experimentation, protocols, and more rational criteria (Langella, 2019; Sawa, 2016). Designers who hybridise their discipline to such an extent that they switch to the scientific laboratory as a working environment need further specific skills (often explicitly customized around the scientific sector they are addressing, e.g.special training for the required biosecurity level). There are still relatively few accounts of designers in lab experiences in the Biodesign literature, yet some authors underline how long-term collaborations benefit from a transdisciplinary approach (Sawa, 2016; Crawford, 2021; McComb and Jablokow, 2022). Indeed, it is necessary to consider a certain latency period in which the designer (with a pure design background or no previous knowledge of the field/organisms/material to be scientifically addressed) learns and absorbs scattered information before actually being able to practically participate in any scientific lab activity.

Despite the great interest in this emerging professional figure, Biodesign is still a challenging field to enter (Crawford, 2023). To date, it is hard to tell if there is a real request from the market for what the community intends as a biodesigner (namely, a designer working across design and science). To find a tangible example, the American website *biodesignJobs.com* is currently one of a kind, providing biodesign jobs alert; however, when searching for design job offers on this very platform, there are almost no positions matching the general idea of a biodesigner as intended by the biodesign community.[10] This might be related to the fact that many biotechnologies are still in their infancy, thus making biotech startups and companies more oriented to hire scientists or laboratory technicians rather than designers; this, in turn, is the reason why biodesigners currently thrive on personal practice or tend to gravitate around some inner circle of dedicated academic research labs or Biomakers spaces.

Research through design as an autoethnographic form of inquiry to clarify the roles of biodesigners

The author analysed the biodesigner figure in the context of a doctoral research path (intersecting Biodesign, Material Design and Design for Sustainability) to better frame biodesigned materials and artefacts' potential for both conventional and regenerative sustainability (Pollini, 2023). Four Research through Design (RTD) projects have been activated, based on collaborations with different professionals and institutions, to test the effectiveness of designers in scientific contexts of different intensities. Given the lack of literature on the biodesigner figure, these RTDs have been fundamental to enrich the study on this emerging figure from a first-person-perspective (Varela and Shear, 1999; Tomico et al., 2012; Forlano, 2021), adopting an autoethnographic approach (Neustaedter and Sengers, 2012; Méndez, 2013). This research path was also based on the fact that, among the few references found, the most specific and descriptive on the topic had an autoethnographic approach, indeed reporting the designer's first-hand experience in the lab. Sawa (2016) shares a quite personal point of view as a biodesigner working on algal biotechnologies in a university research laboratory: she describes in detail the dynamics with colleagues, the peculiar rules of the lab setting, her workspace and its relationship with other spaces in the lab; as it clearly stands out, she used her very personal experience to address specific concepts concerning the aptitude and challenges of a biodesigner working in a scientific lab. Crawford (2021) centers her discourse on direct accounts of her journey aimed at developing a photosynthetic ceramic bio-composite material in a university research lab; such autoethnographic framework allows her to reflect on working dynamics that only a first-person perspective can grasp, such as the importance of the informal exchange of knowledge (across different media and modes of communication) between designers and scientists. These two contributions show the potential of qualitative inquiry derived from the researcher's first-hand experience.

Such a research approach, makingthe researcher the subject of inquiry and relying on personal experience of a phenomenon to produce knowledge, can be used to *observe* "one's own experience within a particular group or subculture, one's own usage of a technology, or perhaps a designer's or researcher's own process of designing and using a new artifact" (Desjardins et al., 2021). Jones (2013) points out how autoethnography, a method associated with a first-person perspective, can help gather the "granular experience of the every day," particularly fitting for design as a highly embodied practice based on senses and materiality. Bochner (2017) describes autoethnography as "the genre of doubt" and a method of qualitative inquiry that allows scholars to maintain an emotional and personal connection with their research. This method has been used for qualitative data across various disciplines, constantly based on self-observation and self-reflection. Widely addressed in Human-Computer Interaction studies, first-person approaches have been recently used also to deepen recursive issues arising in Biodesign, such as the perception of the non-human agent (Ofer & Alistar, 2023), or the cohabitation in multispecies contexts (Tomico et al., 2023).

The overall study presented here has addressed RTDs as a method of qualitative inquiry through personal engagement; its original contribution lies in the focus on the different nuances of engagement with scientific disciplines, thus focusing on how different working conditions and circumstances influence the work of the biodesigner. This approach seemed ideal to embrace both the sensory and subjective side of Material Design and Biodesign practices, which strongly rely on informal and often tacit practical knowledge in tinkering and biotinkering activities (Parisi et al., 2017; Rognoli et al., 2021). The autoethnographic study was carried out during four author's RTD activities (which involved different workplaces, methods, materials, and organisms), to gather information on the designer's role in scientific contexts of different intensity, addressing the limits and advantages of design methods, testing the designer's integration in different disciplinary contexts and the adaptation toward transdisciplinarity. Each RTD has been addressed through target autoethnographic research questions (detailed in the next sessions dedicated to RTDs). The author used filed notes (Jones, 2013; Phillippi and Lauderdale, 2017), systematically collecting sketches, written notes and photographs while carrying out the various RTDs projects. The collected notes were subsequently reported in a final text and analysed through descriptive coding (Saldaña, 2016); in particular, the notes of each RTDs were compared to evaluate recursive patterns and contrasting elements of the four experiences. Thanks to this self-reflective inquiry, the author resumed the most significant insights on her role as a designer in dialogue with science from different perspectives and workplaces. To reinforce these early findings, the autoethnographic report based on the field notes was subsequently cross-referenced with (1) targeted questions to the scientific lab colleagues about the author's biodesign activities, (2) the results of two wider surveys carried out among other biodesigners and life sciences professionals, and (3) the insights from 16 interviews carried out with biodesigners, entrepreneurs, professors and researchers in the field of Biodesign[11] (Pollini, 2023).

Relying on scientific feedback and inspiration is fundamental for Biodesign; however, the autoethnographic investigation was also focused on understanding whether design methods could fit into scientific research and actively contribute to scientific innovation. Some testimonies in the literature argue that designers can contribute to scientific knowledge (Calvert & Schyfter, 2017; Driver et al., 2011; Sawa, 2016); the objective of this study is to discuss the prospects and bounds of Biodesign at the very moment scientific research takes place, investigating the possibility of actual contributions by the designer in different scientific contexts - from working in a makerspace with a group of designers to being part of a scientific lab as the only designer. A brief description of each project follows, aiming to show how the RTDs were planned as an autoethnographic research tool while contributing in parallel to Biodesign and scientific research in different fields.

RTD1, Biotinkering with kombucha

The first project focused on *biotinkering with kombucha* and aimed at strengthening the author's discourse around biotinkering[12], as one of the fundamental activities defining a biodesigner (Rognoli et al., 2021; Pollini, 2023). Biotinkering activities with bacterial cellulose (BC) were carried out within the DeForma project, with a team composed by PhD students and researchers from the design department of Politecnico di Milano, in the university makerspace equipped for the growth of BC. Specific autoethnographic RQs wanted to investigate how the biotinkering activity might inform the Biodesign process, and how working among other designers in a university makerspace could embed a scientific approach in Biodesign. BC growth is a widespread activity among biodesigners, especially taking advantage of the fermentation process of kombucha, which can be harvested in low-tech laboratories, with simple equipment and skills. In dealing with kombucha BC, biotinkering can be performed during the growth phase, acting on the liquid culture or the BC layer, while further tinkering activities can be done once the material is harvested. Colours, thicknesses and textures can be programmed during the cellulose growth or obtained through low-tech processes on the already collected

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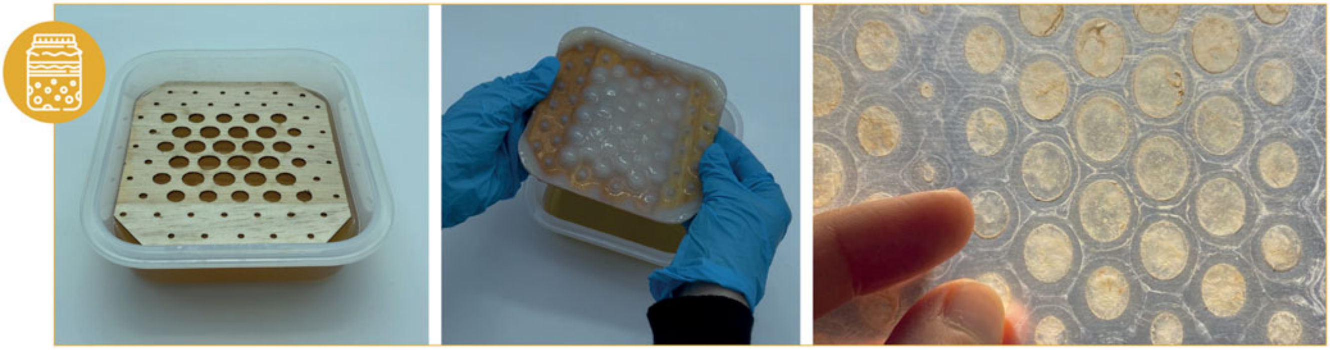

Figure 2. Incremental stages of the process while using cellulose masks to create textures derived from different BC thicknesses.

cellulose. The author had prior experience working with BC; therefore, in this project, her biotinkering activity focused on more specific experimentations, such as testing the circular potential of BC growth (e.g., feeding it with different types of carbon sources from food waste), embedding technological components after or during the BC growth, testing low-tech/cost treatments of the dry material, and testing BC response to different materials during the growth phase. In particular, the author's biotinkering activity was oriented toward testing the organisms' response to different material stimuli, attempting a more empathetic understanding of their response. The fermenting culture's different reactions to various materials led the author to develop a new technique that uses cellulose masks to create patterns derived from different controlled BC growth thicknesses (Figure 2). In this project, the author teamed up with other researchers in the design field, and the knowledge transfer remained within the (bio)design community. A dedicated space and some tools have been implemented for BC growth in the preexisting makerspace, such as incubators, desiccators, a refractometer and a liquid pH metre (in addition to various fermentation vessels). Minimal protective equipment was required, such as gloves and masks. The initial growth of BC occurred following standard methodologies found in the literature. After this initial phase, the author's biotinkering activity took a less standardised approach, also thanks to her previous knowledge of BC growth. She kept track of the experiments carried out through written notes of the recipes, treatments and organisms' response (e.g., grow rate, BC colour and homogeneity). The author's biotinkering phase did not involve any particular scientific methods other than recording experiments and constantly observing the organisms' growth and responses to stimuli; therefore, a sort of participatory observation (Ciesielska et al., 2018), empathy and interpretation (Koskinen, 2023) have been valuable approaches in this biotinkering activity.

RTD2, Bioreceptivity for biomonitoring

The second project was activated to test the theory previously developed by the author on Bioreceptive Design. Bioreceptivity is "the aptitude of a material to be colonised by one or several groups of living organisms" (Guillitte, 1995); derivatively, Bioreceptive Design "occurs every time a material/artefact is intentionally designed to be colonised by life forms" (Pollini and Rognoli, 2021). The autoethnographic research was focused on the following RQs: How is the biotinkering activity informing the design process when a more precise project's brief/goal is set? How can a biodesigner address professionals in other disciplines and confront them in interdisciplinary environments? How do biodesigners should present their hypotheses when confronting other disciplines? The author involved an expert in lichenology for collaboration after writing a research proposal focused on developing bioreceptive materials for lichen and moss growth. The primary hypothesis of the project was to understand if bioreceptive design can serve the supply and exposure of lichens and mosses in urban areas for biomonitoring activities – a pool of techniques that uses these organisms as bioindicators of air quality (Contardo et al., 2018; Świsłowski et al., 2022). The initial research proposal aimed at solving a supply issue since these organisms grow slowly and their collection in pristine environments for biomonitoring activities must be limited, considering the time necessary for their regeneration. The author's knowledge of these organisms was initially derived from the literature and subsequently implemented by discussing the project with the expert. The design activity followed the methodology outlined by the author for Bioreceptive Design (Pollini and Rognoli, 2021), addressing also Biomimicry (Benyus, 1997), and computational design (Pollini et al., 2020). The fundamental steps of this reiterative project are prototyping, exposure and evaluation of colonisation. Each design choice concerning the prototypes has been discussed and evaluated with the expert. The prototypes were made with different materials and textures: some were displayed without further treatments to evaluate spontaneous colonisation (which depends on many variables and can be very slow - up to years), while on others transplants were carried out for a more rapid proof of concept (Figure 3). The prototypes are now following a scientific bioreceptivity evaluation process, constantly monitored by experts in the botanical garden of Siena, Italy. Early findings show positive results from transplants and spontaneous colonisation of mosses and of a pioneer species, Cocconeis placentula, an alga often preceding lichens and mosses (Pollini et al., 2023). Although the initial focus of the research was on biomonitoring with lichens and mosses, the early results suggest that the project can be expanded , contributing to biophilic urban resilience and positively affecting biodesign, architecture, biology (especially lichenology and bryology) and citizen science. The author has prototyped within design university laboratories equipped with additive manufacturing machinery, in ceramic laboratories and partly in her private studio. Each place was functional for the type of prototype to be created. The design methods used were bioreceptive design, biomimicry, computational design and additive manufacturing. Due to the collaborative nature of such a project, the scientific methods related to treatments, exposure and evaluation of the prototypes' bioreceptivity are carried out by the lichenologist through specific measurements and microscopy (Ibid.). In this project, the biotinkering activity occurs in "slow motion" given the

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Figure 3. Prototypes, transplants and first signs of spontaneous colonisation on bioreceptive materials.

growth rate of these organisms; therefore, experiments are planned as a mix of scientific hypotheses and an initial biotinkering phase mainly based on the observation of the targeted organisms in the wild. The study aims to find bioreceptive design material variables to support the scientific method of biomonitoring through lichens and mosses. The collaboration with an expert allowed immediate validation of the research proposal and formed the basis of a solid knowledge transfer. Further validation of the project took place by presenting the ongoing research at a lichenology conference and collecting feedback from the scientific community (Pollini et al., 2022).

RTD3, Tinkering with silk-based materials

The last two RTDs took place in scientific laboratories and highly scientific environments. The author was a visiting PhD in these laboratories, conducting various experiments and projects as a designer in lab.

The first laboratory experience took place at SilkLab (Department of Biomedical Engineering at Tufts University) when I joined as a visiting PhD for six months. SilkLab is pioneering the use of silk, and fibroin in particular, as a material platform for advanced technology and global health applications.[13] Fibroin, the protein component of silk, is an extremely tunable building-block material that can be further processed to create a vast number of materials with equally broad possible applications from the biomedical sectorto active packaging and fashion (Guidetti et al., 2022). SilkLab had previous collaborations with architects, designers and creatives. The research period at Silklab aimed to test the designer's role in a highly scientific environment. Two autoethnographic RQs followed the previous ones on understanding how biodesigners can confront themselves with professionals from other fields in interdisciplinary environments. Other specific RQs for this RTD were: Which strategies and design methodologies can help position a designer in an interdisciplinary environment? Which are the designer's struggles in a highly scientific environment? Can designers be useful professional figures also in extremely scientific settings? The objective of this visiting period was to address the hypothesis that a DIY-Materials approach (Ayala Garcia and Rognoli, 2017; Pollini and Maccagnan, 2017; Rognoli et al., 2021) could also fit in a scientific lab dealing with advanced materials - such as fibroin, at the core of SilkLab's research. The author had no previous experience working in scientific laboratories, nor experience with the extraction and use of fibroin. For this reason, working in this lab has been the most significant challenge (among other RTD experiences) when it comes to scientific protocols to follow, technologies to learn and use, and the degree of scientific knowledge to assimilate before significantly proceeding in the research. The very first months were devoted to learn the fibroin extraction process and to become familiar with the dedicated processes required to obtain different material results; many initial material experiments were the replication of standard protocols for making fibroin-based films, inks, hydrogels or aerogels. Only after this period the author could design more significant variables in material experiments, relying on a DIY-Material approach and tinkering activity supported by the continuous feedback from chemists and material scientists from the lab (Figure 4). The freedom of experimentation left to the author, together with the availability of colleagues in showing the use of machinery and fibroin manufacturing processes, certainly helped to create the optimal conditions for supporting a DIY-Materials activity in a scientific context. On the other hand, the author's work contributed to the development of two new fibroin-based materials, thus demonstrating the validity of the design approach, albeit adequately supported by a scientific counterpart. In addition, she applied a Material Driven Design (MDD) approach (Karana et al., 2015) to boost other designers and lab colleagues' understanding of the possible application of the newly developed materials. Moreover, the author analysed in detail the lab processes' environmental burdens, also empowering colleagues' understanding of the fibroin-based extraction and materials' impacts. Here, the author was a *designer in lab*, adopting a DIY-Materials approach to conceive new material solutions and using MDD, prototyping, and graphic visualisations to communicate possible applications and environmental impacts of the newly developed materials. She followed various scientific protocols, keeping precise laboratory notes and planning the experiments, albeit with the personal freedom to decide their number and nature within the limits of the materials and machinery availability; the actual knowledge transfer occurred only in the second half of her visiting period, after having assimilated basic notions and protocols which allowed her to generate new insights.

RTD4, Biofabricated edible electronics

The second lab experience took place when I joined as a visiting PhD the ElFo (Electronic Food) research group at the Italian Institute of Technology (IIT) in Milan; this research team is leading the field of edible electronics, a sector close to organic electronics but with the additional challenge of using edible materials for electronic applications.[14] Here, the autoethnography RQs were similar to the previous concerning biotinkering, the designer's integration with a scientific audience, and the work in a scientific

Figure 4. From silk cocoons to material experimentation in the laboratory. The image in the centre shows a series of material samples produced by the author and stored for subsequent evaluation with colleagues.

Figure 5. Samples of developed materials suitable for edible electronics and material tinkering during the workshop.

lab. Edible electronics focus on material edibility, biocompatibility, and biodegradability, positively contributing to (self-)monitoring and targeted body care, addressing also smart packaging and biodegradable robotics. Although still in its infancy, the field of edible electronics is already generating significant scientific interest by imagining a technology that is safe for consumption, cost-effective, environmentally friendly, and can safely degrade within the body or in the environment after serving its purpose. The embryonic stage of the field requires more basic research, primarily focusing on new possibilities of edible materials (Sharova et al., 2020). The author started this collaboration after submitting a research proposal suggesting the experimentation of biofabricated and bio-based materials to broaden the range of materials for edible electronics. The author's previous knowledge of BC biofabrication and edible DIY-Materials recipes, together with the previous experience in a scientific lab, facilitated the challenges posed by this RTD, while also giving results in a shorter time (after an initial briefing based on some material samples and experimentation produced by the author in her studio, the whole outcome was produced in just a couple of days a week for four months). Indeed, soon after the research proposal, the first BC samples of material produced by the author were evaluated, and three possible applications for its testing in edible electronics were identified. In this case, the biotinkering phase occurred during the initial briefing phase. From the author's entry into the lab onwards, she followed the standard protocols for BC growth, planning the subsequent experiments in the lab according to the previously identified research objectives. For the lab phase, she partnered with a materials scientist, and together, they developed new biofabricated material solutions for edible electronics[15]. The materials scientist made the necessary measurements to test the prototypes' validity. At the end of the visiting period, the author gave a workshop to the ElFo colleagues on biofabricated, DIY-Bio and DIY-Materials (Figure 5). The idea for the workshop was born from a request from lab colleagues, given their interest for DIY and bio-based materials. For this activity, the author experimented with a series of DIY-Material recipes that could meet the requirements of edible electronics, creating a series of material samples to show and evaluate with ElFo colleagues during the workshop. The general response to the workshop and its content was positive. Participants saw a way to broaden their mastery of edible materials, profiting from the the knowledge transfer from the design field. The most appreciated aspect of the DIY-Materials approach was the ability to test multiple solutions quickly and easily, perceived by colleagues in the lab as a way to speed up the material research.[16]

Also in this case, the author was a designer in lab, arriving with a research proposal based on her previous knowledge and skills in Biodesign and Material Design. This helped to set the dynamics of the collaboration, structured clearly and effectively from the beginning, to obtain results in a relatively short period of time. For this RTD, the author mainly relied on biotinkering, still following basic BC growing procedures and keeping precise laboratory notes on the planned experiments. As in the case of the second RTD, the first exchange of knowledge already took place in the research proposal itself. Furthermore, knowledge exchange occurred both during the lab research phase (thus contributing to the developement and testing of new BC applications for the sector) and within the final workshop (which allowed the author to share a design

https://doi.org/10.1017/btd.2024.11 Published online by Cambridge University Press

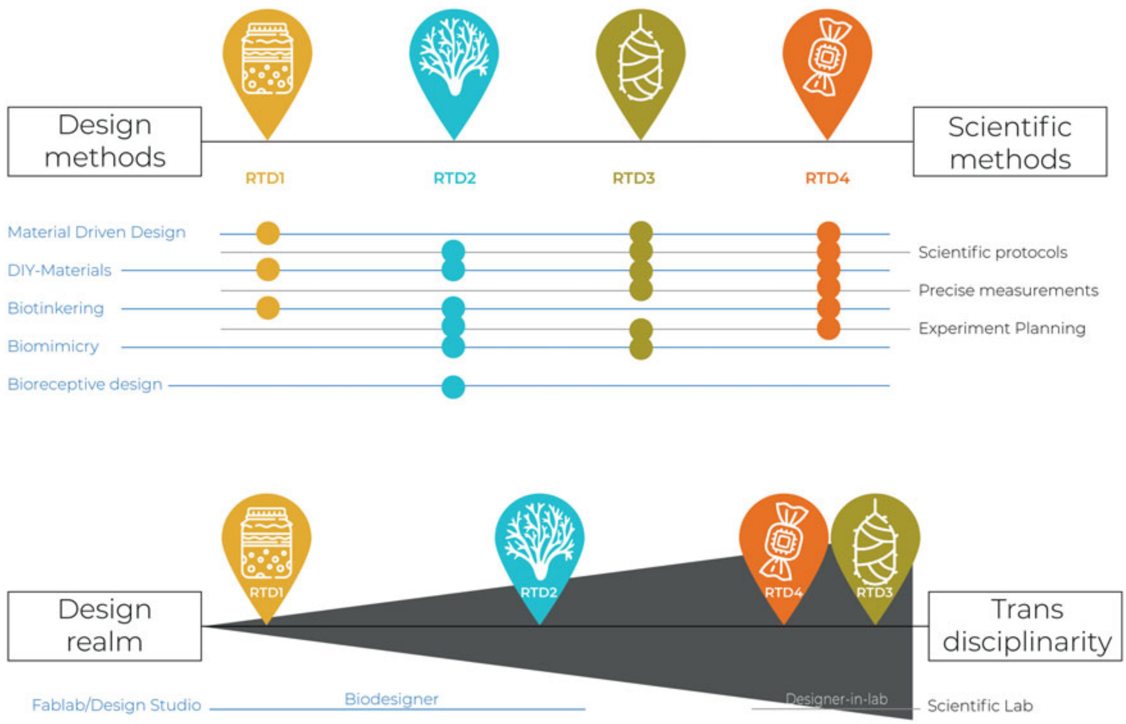

Figure 6. Comparison between the four RTDs concerning methodologies, approaches and work environments.

approach that can be valuable in boosting scientific material research).

The RTDs presented here have been a form of autoethnographical investigation to possibly contribute to what is still a limited body of knowledge about the figure of the *biodesigner* (and the even less addressed *designer in lab*). The four RTDs show that different degrees of cross-pollination between design and science can affect the design process (See Figure 6 for comparisons). Along with autoethnography, RTDs were fundamental to reflecton the different degrees of transdisciplinarity that a designer can assume,and how these degrees, consequentially, could recalibrate design outcomes and potentialities. Transdisciplinary collaborations of different scientific intensities can indeed affect research methods, approaches, skills needed, work environment, and ultimately design outcomes.

From biodesigners to designers in lab

Although Biodesign generally tends to gravitate toward the scientific method (including basic hygiene and safety protocols), the tested approaches highlighted substantial differences in the adopted tools, methods, and languages. Such nuances inevitably influence the designer and the outcomes of the creative process, while also defining two slightly different professional figures. To better define these emerging figures within Biodesign, here follows a clarification based on the literature and the author's early findings through autoethnography.

The main difference between the *biodesigner* and the *designer in lab* can be observed around the workplace. As intended in this article, a *biodesigner* is a designer working across design and science in a low-tech studio which might coincide with his/her own design studio (even garage or kitchen) or with a community or university biolab (or adapted makerspace). With regard to basic scientific and laboratory literacies, a biodesigner is often self-taught or trained via the relatively few Biodesign courses available at the moment. He/she might look for consultancy or collaborations with experts in the scientific field; however, the risks of having no feedback on his/her work from a scientific counterpart might be a challenge, preventing validation and meaningful advancement of the project, especially if it aims to be a viable solution. A biodesigner's working environment cannot be a typical design studio. Usually, the designer's studio is seen as a place to show completed experiments rather than descriptions of methods and processes. For this reason, some scholars proposed the notion of "Design:Lab", to emphasise process transparency and open recipes for experimental research in design, specifically addressing "design research as exemplary processes of inquiry rather than as finalised results" (Binder & Brandt, 2008). The Biodesign phenomenon is helping change this common belief, being process-oriented and keen to open-source philosophy (Myers, 2012). Biodesigners usually build a part of their studio dedicated to biodesign activities, supported by integrating specific tools and machinery, depending on the project and the organism treated. There might not be a clear distinction between the "biodesign operational space" and the desk where drawings, digital visualisations, texts, and notes are elaborated; therefore, the work with living organisms and its observation over time might occur in resonance with the rest of the workflow. In this setting, the inclination towards tinkering and biotinkering manifests innately in the designer, even without planned tests and pre-established materials/equipment, thus empowering experiential and tacit knowledge (Rust, 2004). In these hybrid DIY labs, especially when improvised in a design studio, designers hold responsibility for biosafety standards (on the contrary, community or university biolabs follow standardised rules); nonetheless high danger levels are rarely reached in these settings. Wearing gloves, masks, labcoat or protective glasses depends on the level of security needed for the designer and the organisms. Sometimes, it is also possible to tinker without protective equipment, improving sensorial knowledge of the material/artefact. In this context, the experimented materials are usually known, easily accessible and sometimes derived from food, organic sources or harmless living organisms. Even for non-experts, these conditions make the tinkering activity very "familiar" and "comfortable," usually with little to no fear of managing dangerous materials or machinery; these "relaxed" conditionsallow the designers to freely experiment in an environment perceived as safe and playful.

While discussing the figure of the *designer in lab*, this study describes it as a designer trained for lab skills (e.g., hygiene and security standards, use of specific high-tech machinery), working a significant amount of time in a scientific laboratory (Langella, 2019; Sawa, 2016). Coincidentally, he/she may also be a biodesigner with an already developed aptitude for working between design and science, as in the author's case. Among the many aspects affecting the activity of a designer in a scientific lab, there is, first of all, the training. Specific courses must be undertaken before even entering the lab spaces and being allowed to touch and use chemical components and sophisticated machinery (e.g., Lab Safety Training and Basic Biosafety Training). Lab safety rules require the designer to know which personal protective equipment is required while working-including gloves, masks, lab coats, safety glasses and other wearable equipment. Safety and hygiene rules are very restrictive in scientific labs. This is also because multiple research activities might coincide in a laboratory, none of which must pose risks or be put at risk by failure to observe these rules. This condition could prevent a designer's experiential learning, given the protective equipment's partial coverage of the senses, however inevitable. Protective tools might affect the material experience of the designer, perceiving a part of the senses as "blind" (most of the time this happen to the touch, prevented by gloves), not the ideal condition for a tinkering activity, which, by definition, relies on senses (Parisi et al., 2017). From a designer's point of view, adapting to the guidelines of the laboratory may limit sensory exploration, initially seeming like a loss of the playful approach associated with material experimentation. However, significant advantages counterbalance the situation, namely that of working with materials, solutions and machinery capable of significantly expanding the potential of the material sources examined. Some materials can hardly be processed in low-tech and improvised labs (e.g., aerogels). High-tech machinery can expand the designer's potential for experimentation; therefore, the tinkering of a designer who enters a scientific laboratory for the first time is an ongoing work of assimilation of new notions that modify and expand the range of possible material experiments imaginable. Under these circumstances, the initial limitation perceived on a sensorial level due to the laboratory context can quickly be understood as empowered experimentation enhanced by the very same high-tech tools. Designers might feel disoriented in a lab, especially if they lack previous experience. For this reason, as also reported by other designers who had a prolonged stay in scientific labs, following the work of colleagues and having informal conversations with them is essential to properly learn how to move around the laboratory and progress in the research (Sawa, 2016; Stefanova, 2021; Crawford, 2023). By the way, this is not an unusual condition, since labs often foresee shared workspaces, configured as more similar to a makerspace than a private design studio. Being able to see and "copy" the tricks of scientists allows the designer to acquire experiential knowledge, generally understood as a way of knowing and understanding through direct personal engagement, addressed as a key aspect to be integrated into cross-disciplinary collaborative practice (Nimkulrat et al., 2020). That of the designers in lab is a transdisciplinary work, interacting daily with STEM professionals. They not only receive continuous feedback and validation from a scientific audience but also embrace the methods and languages of scientific practice, striving to be understood by their colleagues. This fundamental step helps biodesigners acquire a more practical approach through learning by doing, making Biodesign a less speculative practice. Designers' prior knowledge of the material or lab environment can significantly facilitate the research process; if this is not a prior condition, a few months of basic learning must be considered depending on the project/material to be addressed. Despite a less spontaneous and immediate start, a designer in lab might achieve more sophisticated outcomes, empowered by lab setups and colleagues' feedback. However, for the author, having been able to test the different nuances that a biodesigner can take on was fundamental to understand that neither of these two figures is more correct or in any way better than the other. Depending on the project's objective, certain designer roles and methods best serve the project's purpose. For instance, the research and the development of the bioreceptive material within RTD2 required scientific theoretical support to guide design activities in creating bioreceptive prototypes, later tested in the natural environment. In this case, a laboratory is only needed when analysing the results. In contrast, RTDs 3 and 4 would not have produced similar results outside of a scientific laboratory throughout the entire research period. The key factor seems to be acquiring an aptitude beyond specific knowledge. Possibly this aptitude might coincide with the mental elasticity that places the designer as a facilitator of connections among different concepts, skills and disciplines. For this reason, before stating that today we are already facing two different professional figures in Biodesign, it is more correct to start addressing different nuances within the possible activities of a biodesigner. However, this distinction may become necessary with the consolidation of practice and greater integration of design in scientific disciplines. These RTDs have confirmed that designers' collaborations with life sciences professionals are powerful triggers capable of advancing the field of Biodesign with new and innovative material solutions, and that a designer can contribute significantly even in highly scientific environments.

Conclusions and impact statement

On the trajectory of Biodesign's consolidation, this study highlights the different nuances that the biodesigner can take on, working in contexts of different scientific intensity. This gives space to every type of creative-expressive approach, as well as projects that require greater in-depth analysis and scientific validation. The latter, considering the importance of sustainability for Biodesign, is particularly valuable while evaluating the projects' outcomes.

Designers are lifelong learners; this attitude is quintessential for hybrid professionals willing to operate in cross-displinary contexts, such as Biodesign. With the consolidation of the field, in addition to the democratisation of science, we are close to seeing a "designification" of it. With adequate preparation and the right opportunities, a designer can contribute positively to scientific research, even working in a transdisciplinary way as a designer in lab. The intuitive and creative design approach may cause some friction in this context; however, such *designerly way of knowing* can be beneficial when designers are involved in collaborations with scientific disciplines.

Data availability statement. Data availability does not apply to this article.

Acknowledgements. Special thanks to the Materials Design for Transition research group from Politecnico di Milano, headed by Professor Valentina Rognoli, whose feedback and inspirational discussions positively influenced the author's doctoral research. Moreover, a special mention goes to all the experts and research groups who greatly supported and collaborated on the RTD phase: the DeForma team, Doc. Tania Contardo, the SilkLab research group, and the ElFo research group.

Financial support. This contribution resulted from the author's doctoral research; the doctoral scholarship from Politecnico di Milano supported part of the work cited in this publication.

Competing interests. The author have no conflicts of interest to declare for this publication.

Ethics statement. Ethical approval and consent are not relevant to this article type.

Notes

1 Readapted from: www.merriam-webster.com/dictionary/biohacking
2 A couple of examples of well-known and established biomakerspaces can be Genspace in New York (https://www.genspace.org/) and Waag in Amsterdam (waag.org/en/lab/open-wetlab).
3 A variant of the STEM educational approach including Arts (Science, Technology, Engineering, Arts, and Mathematics).
4 Retrieved on 12/04/2024 from: jlsteenwyk.com/arts.html
5 Eduardo Kac is well known for his bioart works, especially for creating organisms with new genetic attributes. Retrieved on 12/04/2024 from: www.ekac.org/transgenicindex.html
6 Retrieved on 12/04/2024 from: www.ekac.org/manifesto_whatbioartis.html
7 The emergence of courses and dedicated labs for Biodesign education seems to originate first in Western countries, quickly reaching a global audience. We can refer to IAAC, TU Delft, UAL and UoE in the UE; to Newcastle University, Royal College of Art London and UCL in the UK; MIT Media Lab and the Rhode Island School of Art and Design's Nature Lab in the US; the Symbiotica Lab at the University of Western Australia – to name a few.
8 Retrieved in April 2023 from: www.bluecity.nl/how-to-Biodesign and: emmavanderleest.com/digital/the-growcast-podcast-about-biodesig
9 E.g., See the professional background of Susan Lee, Maurizio Montalti, Natsai Audrey Chieza or Damian Palin, to make a few examples.
10 Checked at biodesignjobs.com on 08/29/2023; 10/22/2023; 12/30/23; 04/13/2024. Hopefully, this data may change in the future when biotechnology and Biodesign become consolidated fields.
11 A selection of expert interviews is accessible on the website healing-materialities.design where part of the doctoral research is shared.
12 The term biotinkering addresses a tinkering activity dealing with biological matter, including living organisms.
13 Retrieved in December 2023 from: silklab.engineering.tufts.edu
14 Retrieved in July 2023 from: elfoproject.eu
15 The study was presented at European-mrs 2023 in Strasbourg, and a full paper is currently under review for further publication: Ferrarese F.M., Pollini B., Luzio A., Caironi M. (foreseen, 2025) Bacterial cellulose from Kombucha's SCOBY as multipurpose material for fully edible electronics.
16 From the testimonies collected from a survey proposed to participants after the workshop (Pollini et al., 2023).

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