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Scientific Design from A Speculative Perspective

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Introduction

In the international design landscape, there is a progressive growth of examples of "scientific design" aimed at interpreting advancements in research across various scientific sectors in the design of concrete artifacts such as new products, materials, scientific instruments, or machinery. The goal is to bring functional, process, and formal innovation to the design discipline. This design approach requires designers to have specific skills that allow them to engage with scientific subjects beyond their disciplinary boundaries. The quality and evolutionary level of the results depend on factors such as the reliability and importance of the scientific knowledge applied or the utility and alignment of the product with real societal needs. The limitation of many of these projects lies in interpreting science more as a source of inspiration than as a domain of joint innovation.

Speculative Design and science fiction

Scientific design can have a significant impact even when conceived speculatively. Anne Balsamo emphasizes the role of the design process in representing and amplifying cultural values: “through the practices of designing, cultural beliefs are materially reproduced, identities are established, and social relations are codified. In this way culture is both a resource and an outcome of the designing process” (2010, p.3).

Speculative design (Auger, 2013; Dunne, & Raby), critical design (Rosner, 2018), and design fiction (Markussen & Knutz, 2013; Bleeker, 2009) propose products that convey ethical and cultural messages, presenting imaginative visions of alternative presents and possible futures. These approaches, with nuanced differences, explore ethical, relational, and cultural implications of scientific advancements in genetics, nanomedicine, robotics, or synthetic biology. They use rhetorical devices like allegory to elicit emotional engagement and provoke critical reflection.

Dunne and Raby advocate for an expansive perspective, urging the embrace of speculative everything. This approach transcends conventional boundaries, delving into not only product design and human needs but also encompassing a multitude of worldviews, ideologies, and possibilities (Dunne & Raby, 2013). Within this framework of speculative design they introduce the concept of "world-building," primarily achieved through physical artifacts. They characterize these artifacts as components symbolizing entire entities, strategically crafted to evoke speculation within the viewer regarding the world to which these objects are affiliated. Rather than directly constructing worlds, the aim is to allude to or evoke societies and cultures different from their own through the materials and forms of these objects.

Moreover, Dunne and Raby aspire to challenge how people think about everyday life, anticipating that their critical and speculative designs will prompt viewers to engage in a sort of imaginary archaeology. This process renders the familiar unfamiliar, yet remains anchored in "scientific possibility".

Design fiction is an alternative term used to describe design works that envision, speculate, and depict alternative perspectives on design and the realms it inhabits (Galloway & Caudwell, 2018).

DiSalvo (2009) compellingly asserts that the storytelling mechanisms of speculative design and design fiction reside in the formal attributes of design, the expertise of the designer, and the culture of consumption. By possessing an adept comprehension of how products are conceived, developed, and promoted, speculative design projections gain credibility and persuasiveness. This is attributed to the fact that the representations are readily consumable in the present, owing to their visual impact, and are conceivable as potential future consumables, mirroring our perceptions of how authentic products would manifest. Naturally, this prompts inquiries

about what is genuinely under scrutiny and identifies the potential audience for speculative design, as well as who that audience should or could ideally encompass.

In speculative design forms that interpret scientific content, questions related to the impact of science on society and its ethical, relational, and cultural implications are addressed. Design raises inquiries into the potential influence of revolutions induced by genetics, nanomedicine, robotics, or synthetic biology on people's everyday lives. The ethical and social implications of the paths and achievements of science are beginning to emerge as a topic of great interest, particularly within scientific communities where, in recent years, research groups and cross-disciplinary commissions specifically focused on ethical issues have been established (Resnik & Elliott, 2016).

n this scenario, various forms of speculative design observe and analyze the relationships between science, society, economy, and culture to extract instantaneous or synthesized visions, which may take on poetic, celebratory, cryptic, allegorical, polemic, severe, interrogative, denunciatory, or ironic characteristics. The designer serves as a mediator between sciences and society, generally refraining from expressing judgments but instead posing questions with the intent of awakening consciousness, providing input so that individuals can be informed and, consequently, participate in change. Pursuing these objectives, many international experiences in critical and speculative design dedicate ample space to emotional involvement, political and social commitment, surprise, empathy, or dismay, employing rhetorical figures such as allegory.

Speculative design addressing science occupies intermediate spaces between design, art, and science. Its products are primarily presented in alternative contexts compared to conventional design marketplaces, such as art galleries, museums, or the internet. It is crucial that scientific content remains true to its nature, and the choice of aspects to emphasize, as well as the manner of doing so, should be shared with scientists to avoid misunderstandings, incorrect or misleading information on critical issues like those concerning health or the environment. In such cases, the fictional aspect gives way to a more rational critical design.

Designers operating in this context also tackle complex issues with the ambition of achieving a broad and disruptive impact on society and people's ways of living. Their works are aimed at stimulating engagement, reflection, dialogue, and debate among individuals on contemporary issues and the potential implications of current paths in science and technology. However, the themes addressed and the contexts in which they are exhibited involve a decidedly limited and selective audience. It would be beneficial if the tools and experiences developed in recent years by designers working in critical, speculative, and fiction design in relation to sensitive scientific issues for society were amplified to a wider public scale, for example, through installations in public spaces, ensuring that the expressed concepts can have a genuine impact on widespread culture and society.

One of the early Italian designers active in this field was Elio Caccavale, originally from Campania, who teaches and works in England. Caccavale's work occupies an intermediate space between design, art, and science. His products are primarily geared towards occupying alternative realms compared to conventional ones associated with the design market, being exhibited in art galleries, museums, or used in hospitals. However, they aim to have a broad and disruptive impact on society and people's ways of living (Caccavale, Tom, 2014).

For instance, Neuroscope is an interactive game consisting of a container resembling a bottle with an eyepiece at its apex. It allows users to observe the bottom where a monitor is positioned, wirelessly connected in real-time to a microscope located in a neurobiology laboratory, focused on a mouse neuron cell incubator. Through various modes of interaction with the device, the user can remotely act on the incubator and send signals to instruments that determine actions and subsequent reactions of the cells. The signals are designed as atypical for molecular biology tools, and the user's experience is also unusual, involving actions such as virtually stroking the cells. The project arises from the need to enable relational forms between users and neuroscience, which has undergone rapid evolution in recent decades, allowing people to understand principles and logics that have significant potential for human health, otherwise challenging to access through conventional dissemination systems. Neuroscope, like other products designed by Caccavale, serves as a tool to bring adults and children closer to advances in science that can impact their lives. It achieves this through an experience involving elements like wonder, curiosity, but also estrangement, capable of imprinting concepts and messages more deeply into users' memories.

Design engages with languages flexibly and creatively, employing rhetorical tools such as analogies, metaphors, allegories, transpositions, antitheses, and similitudes. The use of metaphors in speculative design, according to Di Salvo, can provide a scaffold for the reflection or investigation proposed by the project, enhancing its communicative effectiveness, accessibility, and connection to the social contexts of the present or presumed social contexts of the future, with a perspective of participation (Di Salvo, 2012). Through these modalities, design can generate original expressive forms and syntactic devices that often deviate from the conventional use of words.

These forms of design are also suitable for addressing the theme of the connection between science and politics, a thorny but central subject in a scientific landscape that increasingly needs support not only from public opinion but also from institutions. Although not all speculative projects are political, avoiding reference to politics in the social contexts where it is usually present can be a missed opportunity.

If the purpose of these design forms is to encourage reflection on contemporary issues and the possible consequences of science and technology, then engagement with politics and the conscious deepening of the treated contents constitute a

responsibility from which design should not exempt itself, fostering not only dialogue and debate but also information and awareness.

Provocation serves to shake off certainty and complacency but may risk being a momentary effect. Design that employs the rhetorical tools of language should fully engage with the issues addressed, sparking curiosity and encouraging thoughtful pursuit until it provokes and awakens action and commitment. The design of these objects, therefore, must draw upon and provide access to a breadth and depth of topics to foster or support substantial reflection. And for reflection to be substantial, it requires a level of in-depth information and knowledge. The challenge and responsibility for the designer, then, are to provide that information, going beyond provocation, in a convincing and productive form, using the tools offered by critical thinking to help structure the complex relationships between ideas and objects.

Speculative Matter

Scientific speculative design can involve the design of matter, giving rise to concrete expressions that occupy a complementary space to design for scientific visualization. This engagement extends to the emotional and conceptual spheres, employing different tools connected to the ancestral and sensual link between humans and matter.

The relationship between design, matter, and science requires the designer not only to narrate the opportunities offered by research but also to raise doubts and foster debate. Design has the capability to address issues of great political and social interest related to contemporary scientific research, presenting them in the form of questions and uncertainties. Communicating through tangible, palpable, and inevitable matter makes the communication and prompting more effective (Langella, 2019).

From a speculative perspective, artifacts should be interpreted as material cultural devices that defy conventional categorizations related to the scope of application and market, adhering to new categories more closely tied to the conceptual, communicative, and narrative spheres. The concept of the device draws from the Latin origin of the term "dispositus," the past participle of "disponere," meaning to arrange.

Products generated by scientific speculative design imply extended and layered intentions. They are not functionally monolithic, as they are not generated from functional requests but are proposed through layers of expressive matter that emit messages through multiple communicative wavelengths: ethical, social, political, romantic.

These products give meaning to the contexts in which they are placed; they are interlocutors rather than passively utilitarian entities projecting human influence onto matter. In any case, they trigger unconventional relationships between humans, matter, and thought. These objects serve as opportunities to question and prompt questions because they appear different from what they seem, surprising and destabilizing, allowing for a pause to read the thoughts they contain. They emerge in the current flat landscape where markets tend to standardize morphologies and messages, depriving things of their identity power, making them all uniform, flat, and generic.

The objects of speculative scientific design challenge the commonplace automatisms of thought and action to open up new opportunities and possibilities for interpreting science and creating interactions between science and people.

In the last fifty years, the relationship between materials and designers has undergone a profound change, with designers progressively accessing, in a more participatory manner, the dimension of production processes and material transformation to construct material experiences (Langella, 2021).

The radical transformations induced by the culture of sustainability and the spread of nanotechnologies and new digital manufacturing processes create new opportunities for collaboration between design and materials, where interactions will be less random and sporadic, and more conscious and constructive.

Design, with its interpretative, predictive, and productive tools, can pursue the entire process of developing new materials, from identifying societal needs to the development of innovative material solutions, up to the production and introduction of new products to the market. This collaboration should occur in respect of other competencies and in synergy with scientists. For designers, new opportunities for research and professional development arise, both in the interpretation of material innovations and in their development.

For the experiences of scientific design interfacing with materials to be fruitful, it is necessary to define rational protocols and interdisciplinary cooperation methods to develop artifacts suitable for conveying new material identities from a developmental perspective, increasingly compatible with environmental balances and market needs.

The world of materials for designers is very different from how scientists and technologists observe it because it constitutes a universe of expressive opportunities through which to manifest ideas and materialize corresponding visions. In the imagination of designers, maps and technical classifications, such as those proposed by Ashby (2013), based on the chemical, physical, and mechanical properties of different types of materials, overlap with interpretations by designers who incorporate references to cultures, symbolic qualities, experiential aspects (Wilkes et al., 2016; Karana, Pedgley & Rognoli, 2015), imaginative, iconic, and sensory elements that delineate the "poetry of matter" (Bachelard, 1983). As Eleonora Fiorani (2000) states, the culture of design juxtaposes a "connectomics" to the constellations of technical properties of materials, connecting materials to objects, design thoughts, intentions, and attitudes of designers who have interpreted different materials through those objects. A system of traces more or less deeply engraved in the history of the anthropological relationship between humans and matter.

The Expressive Potential of Matter

Design now has the opportunity to explore and define new

material experiences by combining the technical and emotional aspects of material development, creating richer and more meaningful product experiences (Thompson, Ling, 2014). Material-manipulating design possesses a strong expressive, narrative, and experiential potential that can be employed across various communicative horizons, delving into the roots of human instinct, sensoriality, ancestral memory, and involuntary memory.

The contribution of neuroscience to this type of intervention can be highly valuable. The digitization, virtualization, and dematerialization of experiences are accustomed to people avoiding physical contact with things and individuals, inevitably making them more sensitive and vulnerable to material experiences. On one hand, balancing the evanescence of the digital through the corporeal component could be considered a responsibility of design to safeguard the psychophysical well-being of individuals. On the other hand, the awareness of having new possibilities to impact emotions, invoke the unconscious, and induce user thoughts could become a powerful tool, based on knowledge of chemical and neuropsychological mechanisms, pheromones, and sensory perceptions. Many of these aspects are studied in the emerging field defined as embodiment, founded on interdisciplinary research integrating studies on the phenomenologies of the living body with neuroscience and cognitive sciences to understand the complex relationships between bodily factors, such as physical and motor perception, and cognitive processes (Van Rompay & Ludden, 2015). To employ these tools, design must interface with various scientific disciplines, sharing not only information but also languages, approaches, and objectives.

Often, self-produced materials remain confined to the realm of limited series, closer to art than industrial production because the processes involved are laborious, expensive, and require too much time for easy replication on a large production scale. Moreover, many of them exhibit limited technical-functional performance, such as durability or mechanical resistance, insufficient for many types of applications. For these reasons, it is essential that designers are accompanied by scientists and companies in material design experiments so that insights and experiments can translate into effective innovations. The contribution of design in defining new material landscapes holds significant cultural and prefigurative value as it urges the design culture to surpass existing boundaries and lay the foundation for making concrete new visions oriented towards different yet possible and virtuous futures.

These experiences are useful for investigating emerging technical and expressive opportunities of materials but also for introducing new drivers in design-related production contexts based on values such as adaptability, reactivity, or environmental sustainability, as seen in experiments with upcycling, living, and growing materials.

Many of these projects anticipate processes not yet mature enough for industrial-scale application, where design plays a triggering role in innovation. For example, in recent decades, many design experiments have explored the production processes of biomaterials through fermentation, such as bacterial nanocellulose (Langella, 2024). Although these processes have been identified by the design world as productive scenarios for a sustainable future, they still appear quite distant from an industrial reproducibility hypothesis.

If bacterial cellulose is a material easily accessible for design because it can also be produced in domestic contexts, other types of materials produced by microorganisms present themselves as a possible response to design expectations and visions. Polyhydroxyalkanoates (PHA and copolymers PHB and PHV with butyrate and valerate), for example, are biobased and biodegradable thermoplastic polymers produced by microorganisms, considered among the most versatile and promising in the array of bioplastics that could replace environmentally impactful polymers such as polystyrene (Li, Yang & Loh, 2016; Rajan, et al. 2019).

These experimental trajectories, less accessible to designers due to requiring scientific laboratory equipment and contexts, constitute a potential intervention area for speculative material design, collaborating with microbiologists and material scientists, contributing strongly to the development of sustainability culture (Parra, Birkeland, Burton, & Siivonen, 2018) with a perspective of More-than-human-centered design (Coulton & Lindley, 2019). In interpreting this role, design responds to the contemporary societal need to be informed about scientific advancements that can bring benefits to the environment and people's health.

Speculative Material Design Experimentation in the Hybrid Design Lab

The Hybrid Design Lab is a research laboratory, project experimentation, and educational initiative dedicated to mutual collaborations between design and biosciences, with a particular focus on biomimicry and sustainable material design. Established in 2006 at the Second University of Naples, it had a laboratory and exhibition space at the City of Science Incubator until 2022 and is currently located at the Department of Architecture DIARC of the University of Naples Federico II.

The Echinodesign exhibition, curated by Carla Langella, Valentina Perricone, Gabriele Pontillo, and Roberta Angari, as part of the research at the Hybrid Design Lab, held at the Città della Scienza museum in Naples from February to October 2022. The exhibition provided an international platform to explore the relationship between design and science through the lens of biomimicry, focusing on drawing inspiration from principles, logic, morphologies, and structures observed in nature (Perricone et al., 2024).

The exhibition featured products oriented towards design, along with artistic and scientific installations developed by invited creatives and scientists who interpreted the theme of echinoids through diverse visuals, drawing inspiration from their biological characteristics and exploring opportunities for transferring principles and models into the fields of design and

art. The products were produced in collaboration with project partner companies. The exhibition's opening was accompanied by international seminars and workshops on biomimicry and sustainable innovation.

Within this exhibition, speculative design artifacts were developed in collaboration with Letizia Verdolotti and Giuseppe Lama from the Institute of Polymers, Composites and Biomaterials (IPCB) of the National Research Council (CNR), a research center dedicated to the development of polymeric materials, composites, biomaterials, biomacromolecules, green chemistry, and chemistry for life sciences.

The *Fragile Foam* lamp consists of an LED light source and a diffuser made of ceramic foam with diatomite and silica. The morphology mimics the veined structure of a sea urchin spine, but intentional fragility is designed into the foam, creating cracks during drying that allow light to pass through. Through the rhetorical figure of metaphor, these cracks represent the fragility of the current fossil-fuel-based energy system.

Also part of the *Echinodesign* exhibition is *Seventy Fossil,* a lamp created through upcycling a 1970s diffuser updated with ceramic foam containing aluminum and silica. The foam, developed at IPCB under Letizia Verdolotti's research group, covers an obsolete object to render it eternal, analogous to nature's process with fossils. The lamp aesthetically alludes to the Pyritization process, a form of fossilization where pyrite can produce partial permineralization due to bacterial activity in anaerobic conditions, filling cell spaces with microcrystals of pyrite. Often, oxidizing conditions near the surface alter pyrite into iron oxides. The speculative message the project conveys is that, similar to how nature extends the life of organisms to make them eternal, design should apply analogous strategies to extend the life of objects, delaying the point when they become waste.

These examples serve as illustrations of the ways speculative material design can take, employing a speculative approach to raise societal awareness on crucial themes such as environmental sustainability and design. In this manner, design has the opportunity to effectively counter the technological determinism that currently pervades many of our narratives, offering a critical and creative alternative to the thought of an inevitable future of global destruction by proposing a plurality of possible futures. To achieve this, it is useful for design to venture into extreme speculative directions, generating design theories and methodologies based on new alliances that surpass anthropocentric views to address the expanding universe comprised of algorithms, forms of life, and artificial and natural intelligence that can contribute synergistically to design practice (Coulton & Lindley, 2019).

Figure 1. *Fragile Foam.* Lamp with ceramic foam diffuser with diatomite and silica. The fragility of the material filtering the light alludes to the weakness of the current energy system based on fossil fuels. Authors: Carla Langella, Letizia Verdolotti, Giuseppe Lama.

Figure 2. *Seventhy Fossil*. Lamp made with a recycled diffuser from the 1970s updated with ceramic foam containing aluminium and silica to allude to the processes of fossilisation as an extension of the life of objects. Authors: Carla Langella, Letizia Verdolotti, Giuseppe Lama.

Figure 13. Development Process of the Fragile Foam Lamp at the Laboratories of the Institute of Polymers, Composites, and Biomaterials (IPCB) of the National Research Council (CNR).

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