(Re)Active Materials.Well-Being's Concept Evolution and Advanced Material Innovations

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Proceedings of the 8th International Forum of Design as a Process

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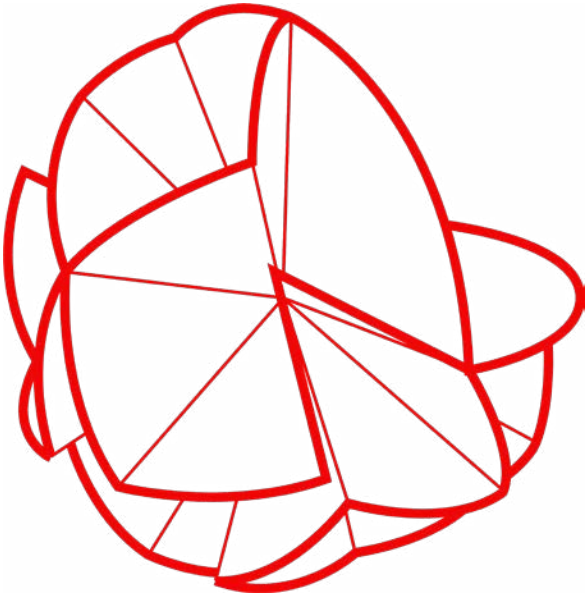

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The Latin Network for the Development of Design Processes is a group of researchers, academics, students and business professionals of Latin languages and cultures who study and operate in a particular field of design known as design processes. They meet in a Forum, conceived as an international specialised conference, to engage in lively discussions and debates about their studies and experiences.

The Network was founded in 2008 with the “Carta di Torino” manifesto. Since its very beginning, Professor Ph.D. Flaviano Celaschi has been leading a team that, over the years, guaranteed the cultural and scientific focus of the members of the Network, fostering inter-institutional cooperation. Since 2015, the Network has been hosted by the Alma Mater Studiorum – Università di Bologna, within the Advanced Design Unit (ADU) of the Department of Architecture, coordinated by Professor Ph.D. Elena Formia.

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Advanced Design Cultures. The Shapes of the Future as the Front End of Design-Driven Innovation
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(Re)Active Materials. Well-Being's Concept Evolution and Advanced Material Innovations

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Abstract
The article aims to read the transition of material design approaches identifying an evolutive models with major principles and contribution into the health improvement through material innovations. The analysis follows a bottom-up approach, using a case-based reasoning methodology to study well-being concept evolution and identify new material experimentations frontiers within three approaches: *Imitative*, *Augmentative*, and *Mutational*. The contribution of the article reflects and suggests the introduction of new material design approaches to manage the design of advanced materials' behaviuors in their future development, highlighting their potential impact on user satisfaction and acceptance, collective welfare improvement, performance optimization, and environmental concerns.

Keywords
Advanced materials
Performative materials
Hybrid processes
Interdisciplinary research
Material design

Introduction

> "Understanding the interaction between the individual and the systems / objects that surround him [...] is fundamental to carry out projects "on a human scale" *(Sicklinger, 2010, p. 223).*

In the last 50 years, technological progress and the change in economic conditions have fueled a (un)balanced global prosperity. In today's society, there is a growing need to overcome established standards and models that are no longer working (United Nations, 2015), imagining new ways of prospering without compromising future developments (WCED, 1987). The future must be interactive and smart (Ferrara et al., 2018), and advanced materials are crucial in enhancing human conditions. Through an interdisciplinary approach, innovative technology can be integrated into advanced materials fostering a more sustainable and symbiotic relationship between the environment and matter for the well-being of individuals and communities (Tosi & Rinaldi, 2015). This analysis aims to read the transition of material design approaches, identifying evolutive models with major principles and contributions to health improvement through material innovations. The contribution reflects on and suggests new material design approaches to managing the design of advanced materials' behaviours in their future development. The article discusses three approaches (*imitation, augmentation,* and *mutation*) by providing case examples.

Behavioural materials

Technological progress has offered to innovate materials and conceive tools to address human needs for progress (Ashby & Johnson, 2010), improving the performance and quantity of newly available substances over time. These rapid advancements enable flexible and intelligent materials – with programmable properties (Oxman, 2010a; 2010b; Gilbert & Ellis, 2019) – to achieve versatile abilities and organic growth, too (Langella & Santulli, 2017). The increase in the significance of innovation studies in various fields contributes to designing upgradable and performative materials' behaviours, overcoming human limits and narrowing the relationship between individuals' and artefacts' surfaces. The alteration of materials has led to evolution from a general characterization of mechanical, physical, thermal, electrical, and chemical performances (Cornish, 1992; Ashby & Johnson, 2010) to wholly controlled and more sensitive properties (Ferrara, 2016; De Giorgi et al., 2020; Lerma et al., 2022). Following this progress, increasingly eco-efficient strategies inspired by natural resilience are spreading and exploring transversal properties and realms linked to the *Material Experience* (Karana et al., 2015). Biological resilience and natural efficiency have once again become good quality indicators (McDonough & Braungart, 2002; Franklin & Till, 2018), stimulating designers and manufacturers to refer to this pool of resources to develop consistent alternative solutions.

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Well-being evolution

In ancient society, well-being was often equated with wealth, power, and material possessions representing unsustainable patterns. Over time, the concept of wellness has evolved (Vezzoli & Manzini, 2007), and a holistic perspective has been advocated in contrast with past values and assumptions (Ceschin & Gaziulusoy, 2016). The human factors, as a part of a complex ecosystem, have become the focus of current design practices (Germak, 2008), with a growing emphasis on mental health, emotional well-being and evolution of wellness in equilibrium with contexts, ethics, and cultural aspects (Tamborrini, 2009). Despite scientific and technological ameliorations, new development is still necessary to meet evolving needs (Tamborrini, 2009), given the rapid expansion of the population. Multidisciplinary collaborations and systemic approaches are achieving centricity in pursuing sustainable strategies of development to address societal challenges (Ceschin & Gaziulusoy, 2016). In that sense, the article highlights the crucial role of design in promoting interdisciplinary exchange between technical-scientific and social-humanistic disciplines to re-design sensitive, augmented, and experimental solutions towards new human experiences of the world.

However, the design of a balanced relationship between individuals' needs and external ecosystems remains a significant challenge for design practitioners in fostering a shared ethic of care for all beings (Tosi & Rinaldi, 2015) and all the systems involved. Some interesting case studies differing in terms of goal and time can be read crosswise to intercept connections from a design point of view to understand how the well-being concept has evolved around specific methodologies.

The article intends to answer these questions: How can advanced materials respond to the needs of both humans and the environment through design strategies? What is the degree of influence of materials in the (re)generation of well-being and comfort meanings? The influence of materials on the human experience below three approaches interpretated from the literature analysis: *Imitation, Augmented*, and *Mutational*, have been discussed and analyzed in the following sections.

Materials and method

According to the literature, the article proposes an ongoing development study focusing on material design approaches that can be integrated into the engineering and scientific ones (Olson, 1997) towards a shift of focus on a more symbiotic relationship between humans and matter. The analysis follows a bottom-up approach using case-based reasoning methodology (Zambelli, 2022) to study the well-being evolution explained through three material innovation examples Fig. 1. The article introduces three hypothetical approaches interpretated by authors both from the literature review analysis and case study observation, which symbolize the degree of material influence on human perceptive experiences. The goal is to read an evolutive transition in material design approaches for the health improvement towards new strategic ways to manage the design of advanced mate-

rials' behaviours. The first section focuses on imitative practices that draw inspiration from natural models and biological mechanisms to design efficient artefacts – known as mimicry design (Benyus, 1997; Langella, 2019). The second concerns augmented systems utilizing advanced technologies to expand human sensory limits and provide more sensitive solutions integrating intangible features (Ferrara et al., 2018). The last section advocates for a shift in design priorities through foresight advances in materials hybridization, as the pioneer Oxman (2013) pointed out, by exploring speculative scenarios with high technological development where the integration of living and evolving materials can optimize human bodies.

Cases' strategies have been explicated to highlight principles and effectiveness in the problem-solving approaches proposed. Finally, the methods have been summarized to open a discussion and promote further research areas of inquiry.

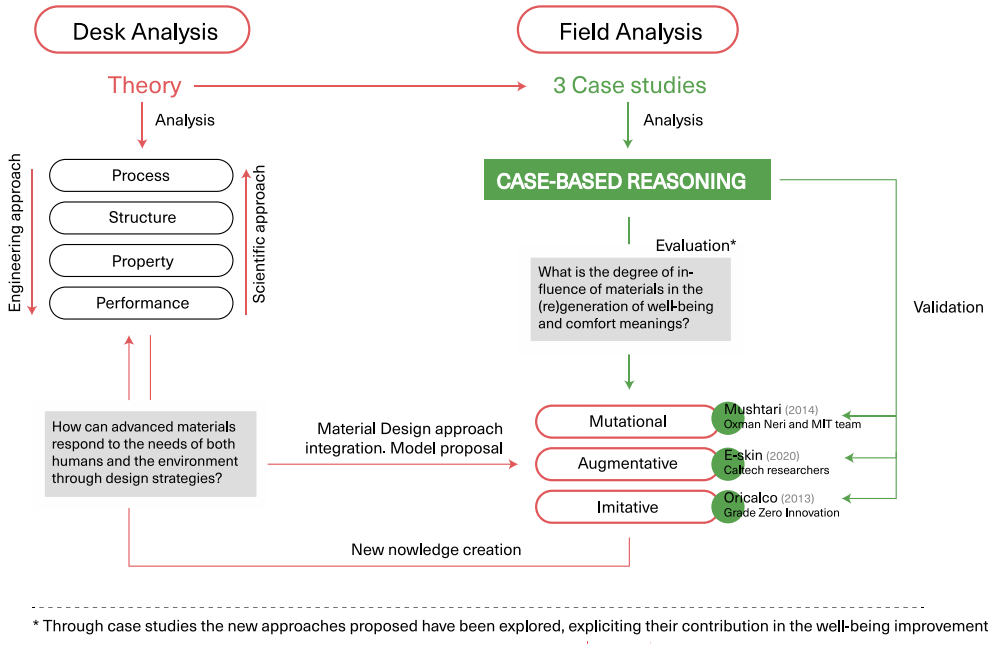

Fig. 1
The cycle of the research analysis. Credits: Author.

Imitative approach

The assumption of natural models for design inspiration has ancient origins. It focuses on the biological problems related to the life of natural organisms (Langella & Santulli, 2017), whose evolution offers correspondences and analogies with modern industrial processes. Nature offers an inexhaustible source of design inspiration, providing models of efficient biological mechanisms that can be reproduced in artefacts through *imitative* approaches (Salvia et al., 2009; Bengisu & Ferrara, 2014; Franklin & Till, 2018). Technological and scientific advancements have led to hybrid materials with complex structures, properties, and behaviours that can be programmed on microscopic and nanometric levels to respond to specific problems and design needs (Langella, 2007). *Oricalco* by Grade Zero Innovation (Grado

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Zero Innovation, n.d.; Langella, 2019), a thermosensitive smart shirt, is an example of a self-adaptive garment inspired by biological adaptation mechanisms to extreme climatic conditions. Thanks to the super-elasticity of shape memory metal alloy, the controlled alteration of materials' shape (sleeves) to external variations (temperature) improves the efficiency of ordinary artefacts, making them capable of exchanging forms of energy with the external environment (Salvia et al., 2009) and provoking active performances. Material advances through *imitative* strategies have led to the following:

- Draw from ecosystems' functional, engineering, chemical and electrical solutions (Langella, 2019).
- Actively modelling hybrid matter
- More effective properties and behaviours.
- Microscopic and nanometric manipulation towards wider needs (Langella, 2007).

Augmentative approach

In addition to the manipulation of the material – as seen previously with the *Oricalco* project – advanced technologies allow expanding the human sensorial limits, providing designers with more sensitive solutions and tools (Lerma et al., 2022) and performing multiple activities – monitoring, communicating, stimulating, and so on (Tosi & Rinaldi, 2015). Thanks to miniaturization, augmented materials are slightly introducing multi-sensorial characterization in artefacts which can meaningfully affect the emotions and interactions of individuals. The California Institute of Technology (Caltech) and the Graduate School of Engineering in Japan are international research centres experimenting with *E-skins* devices with flexible electronic biosensors. Their researches reveal the exciting development of artefacts with capabilities of self-regenerate and self-feed[1] (Yu et al., 2020). From robotics to the health care of physical disabilities – assisting in simple contact without the request of specialized experts – intelligent materials may supplement human capacities. However, challenges remain in terms of power, for example, fueling directly by human bodies interference, without comfort loss, and using sustainable resources due to unrenewable, rare and critical materials involved (Zou, 2018). The major contributes of this approach to well-being improvement are:

- The possibility to collect and analyze personal health conditions remotely.
- Collection of data for customized, effective intervention
- Accuracy prediction mechanism for diseases' detection and treatments (Tosi & Rinaldi, 2015).

1
The cathode of the E-skin's biofuel cell is composed of a network of carbon nanotubes coated with nanoparticles containing platinum and cobalt. The anode is a nanocomposite material containing an enzyme capable of breaking down the lactic acid of sweat, which is processed to power the system.

Mutational approach

The last section focuses on "next" materials in which genetic mutation responds to human needs in speculative scenarios with high technological development (Ferrara, 2004). It is referred to ageing and living materials which can offer solutions that intersect and shape an indefinite and fluid future (Oxman, 2010a). Such performative materials can be integrated into the human body, like living extensions, changing its physical and chemical processes according to the new scenarios. The Material Ecology theory and the *Wanderers project* by Neri Oxman (2014) triggered designers to become alchemists and experiment with alive materials through the cross-fertilization between built, grown, and augmented matter (Oxman, 2013). The wearable device project represents an artificial exoskeleton generative designed to perform an artificial anisotropy (Oxman, 2010b), and it is filled with living and evolving matter – bacteria selected to perform functions like absorbing nutrients, digesting biomass and generating energy. Concerning synthetic solutions based on natural processes and biological systems, new research frontiers overcome "terrestrial" barriers and try to break down traditional canons of design practices towards:

- Define future matter identity (Oxman, 2013)
- The study of material's performative capacity to optimize human bodies
- The analysis of reciprocal mutations between synthetic biological systems and individuals.
- Advancing in mutation metrics and control.

Results

The assumption of *Imitative, Augmentative and Mutational* approaches aims to encourage design practitioners to (re)consider fundamental archetype models (Ferrara, 2016; Franklin & Till, 2018) related to the capacity of biological entities to evolve and adapt in different contexts based on open systems[2] procedures (Mancini, 2018). Integrating new approaches in material design practices involves primarily drawing inspiration from nature at different levels of technologization to convey material innovations towards social welfare needs no less than environmental requirements. As virtuality and physicality slightly left products, designers focus on the cultural significance and sensorial aspects to create more adaptive and responsive environments (Ferrara, 2016).

Concerning the models proposed, Fig. 2 shows set of principles assumed by case studies processes analysis. Case study principles have been developed from the comparison between other cases' theory and goals to support provocative interpretations (Cunningham, 1997). The variables highlighted in the figure depict the efficiency, technological advancement, interdisciplinary design approaches, and sustainability, as prioritized principles among others due to their multiple connection with all the strategies involved. In particular, a relevant insight come from bio-inspiration and user-centred methods, such as core values in driving technological and scientific progress that transfers into everyday artefacts,

2
Defined by the Nobel Prize physicist and chemist Ilya Prigogine about the mechanisms that are part of complex systems in the study of thermodynamics. These systems can maintain their structure and growth, evolving through an entropic exchange with the external environment.

implementing new intangible features thanks to sensory interaction and self-modify systems. Moreover, experimental projects like Wanderers make it possible to visualize alternative preferred scenarios, offering concrete directions and strategies to work on. In that sense, the design mediation between advanced technologies, speculative projects and users is essential to facilitate the democratization and dissemination of innovative research discoveries, supporting the scale-up of ideas from laboratory experimentation to mature and appreciated forms. By facilitating the connection between technologies and users, designers can create systems that enhance human sensory capacities and promote broader social welfare in terms of space and time. The principles identified through case studies seek to overtake design research frontiers and challenge its traditional canons, stimulating designers to shape the agency and properties of materials in unprecedented ways. However, due to the growing complexity of cross-contamination and merging realms, interdisciplinary collaboration is essential to manage appropriately and shape materials' behaviours, achieving sustainable efficiency.

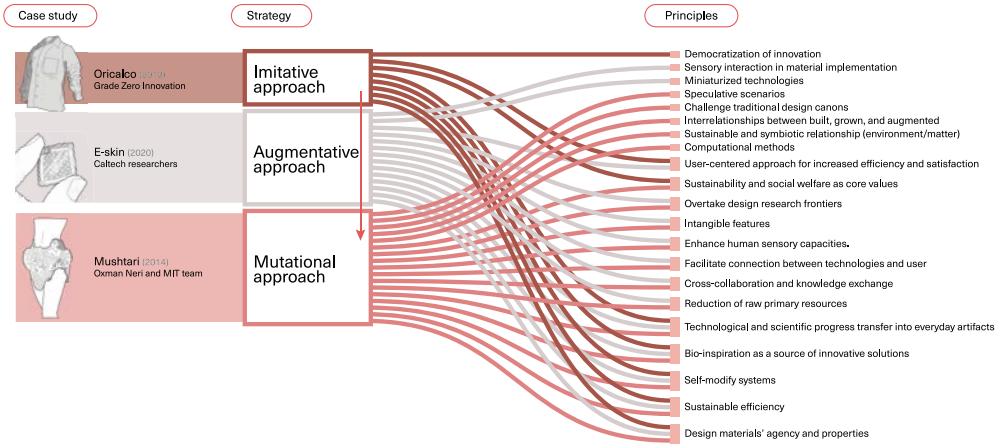

Fig. 2
The case-based reasoning analysis and the principles extrapolated. Credits: Author.

Conclusion

The analysis identifies innovative nature-based material design approaches to optimize the performance of artefacts towards future scenarios and needs. The combination of nature's wisdom and efficiency allows designers to read in the complexity a generative opportunity for a redefinition of the concept of well-being and creating emotional and (intrinsically) more sustainable experiences. The article shows how advanced materials have expanded the boundaries of design towards the hybridization of entities, fields, and systems, allowing them to react to changes and respond to human and environmental needs with higher sensitivity. As highlighted, design practices are crucial in developing open systems of experiences, supporting collective welfare, optimizing the artefacts' performance, extending the sensory limits of the human body, and addressing new environmental concerns. The evolving models of material design, including *Imitative, Augmentative*, and *Mutational* approaches, have

shown significant contributions in addressing societal challenges. Due to the assumption of new approaches, further studies may focus on the following:

- Promoting a symbiotic relationship between humans and the environment
- Identifying new needs and challenges
- Exploring these material design approaches and their potential to address societal challenges and advance well-being.

According to Oxman (2013), the rise of new materiality can establish symbiotic extra-deep interconnection between humans' and artefacts' skins, emphasizing values not directly tangible with senses and influencing – or changing – the way of conceiving the world. Advanced, synthetic, and organic hybrid resources profoundly affect well-being meanings establishing new forms of comfort, caring and adaptation. New forms of material behaviours (Cardillo & Ferrara, 2008), increasingly performative, living and ageing – as they have their own agency and emotional experiences – led to generate more sensitive artificial entities with effective reactions. However, restoring the ethical responsibility that will play a crucial role in designing intangible attributes embedded into them (influencing feelings and emotions) and in planning new sustainable conditions suitable for the life of both natural and artificial systems is fundamental.

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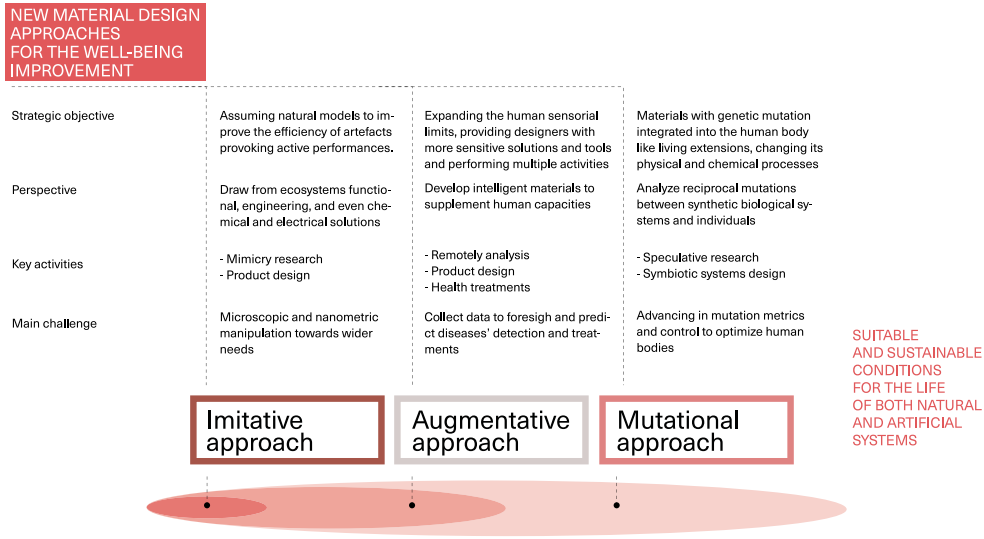

Fig. 3
New approaches for well-being improvement and evolution of Material Design practices. Credits: Author.

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