

Aesthetics and meaning within the circular design discourse: an analysis based on design projects

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Abstract. Design is recognised as a crucial driver of innovation and a facilitator of the transition to a circular economy. While there are numerous strategies to support circular design practices, many tend to prioritise management and engineering processes, neglecting design's aesthetic dimension and its role as a cultural mediator. This research paper aims to revisit the role of design in the circular economy, emphasising its aesthetic and meaning dimensions, and exploring the potential of circular design to trigger socio-cultural change. It analyses existing literature and examines 14 design projects developed within a higher education institution in Portugal, using an abductive approach. The paper develops a conceptual matrix that establishes connections between material function, meaning, and sustainability aesthetics, forming a continuum of design approaches. The findings indicate that material exploration and transformation often shape the ethos of the project, while design intention and aesthetics are emergent components. Moreover, the potential to reach a significant human impact is still quite limited. These results indicate the need to rebalance the ontological contours of the discipline within circular discourse, going beyond functionalism.

Keywords: circular economy; circular design; sustainable aesthetics; design projects

1. Introduction

Circular Economy (CE) is a crucial concept promoted by the European Union (EU) as an alternative paradigm to achieve sustainable development. It aims to manage material and energy flows, in a systemic context, by recirculating them, reducing waste, and regenerating existing systems “by design” (EMAF & Environment M.C., 2016). Despite the existing actions plans, recent studies mention that only limited progress has been accomplished regarding CE implementation in the EU i.e. “only 9% of the world is currently circular” (Circle Economy, 2022), being cultural shifts and consumer behaviour pointed as one important barrier to implementation and diffusion (Kirchherr et al., 2018). In parallel, Design is identified as a key vector of innovation in Europe and “enabler in the transition to a CE” (EMAF & Environment M.C., 2016). There is a growing body of research outlining the role of Design in CE, suggesting useful frameworks, tools and strategies. Recent literature review identified approximately 170 strategies to support the infusion of circular design practices in companies, categorizing them into resources, manufacturing, distribution, use, collection and recovery (Van Kaathoven & Mizuno, 2023). Although important, most of these contributions tend to emphasize management, production and/or engineering processes (ex. circular flows; using less materials; reversed logistics etc.) – showcasing a “design” sometimes detached of its aesthetic dimension and of its role as a “cultural mediator” – standing in-between people, culture, meanings via products, services, interfaces, devices (Branco & Providência, 2018).

Indeed, to realize actual transformation such as those involved in circular economy, both production and consumption systems must change, and as Ceschin & Gaziulusoy (2019) mentioned “in transition (...) there is a need for traditional design approaches that generate specific outcomes (...) belonging to the orders of design: signs, symbols, physical objects, services” (Ceschin & Gaziulusoy, 2019). Thus, while utility and performance are important, other human-centred drivers related to emotions, aesthetics, narratives, interactions, cannot be left aside if cultural change is to be achieved (Lofthouse & Prendeville, 2018).

This research paper proposes to (1) revisit the role of design within the transdisciplinary discourse of circular economy, emphasizing its aesthetic and meaning dimensions within circular projects in light of existing framework of product experience and product semantics. Additionally, since the implications to implement a circular economy are also cultural, embedding products that enable/reinforce social practices and lifestyles, and challenge ways of thinking and perceiving reality, the paper also (2) reflects on the potential of these projects to trigger socio-cultural change, supporting the diffusion of more circular practices.

First, the paper analyses recent literature reviews at the intersection of circular economy and design, providing some reflections regarding the evolution of the design discourse within this context. It also sheds some light regarding the evolution of aesthetics and meaning within design. Next, it uses an abductive approach to analyse 14 design projects developed within a design master course within a higher education institution in Portugal.

2. Background

The Circular Economy has been defined as a complex systemic approach to sustainable production and consumption (EMAF & Environment M.C., 2016). This topic has matured within different research streams, being approached within industrial ecosystems as an analogy between natural cycles and industrial cycles, which posited that industrial processes could imitate nature, reducing the amount of industrial waste (Frosch, 1992). The concept of industrial ecology inspired the debate on extended producer responsibility, which posited that companies needed to be accountable over their own products, beyond the point of sale (Gertzakis et al., 2002). Soon the initiatives, which first focused on waste management expanded to other sectors such as the automotive industry (e.g. Rolls-Royce), photocopiers (e.g. Xerox), amongst others, which redirected their business strategies to use-oriented solutions; and high performance systems (Baines et al., 2007). This inevitably had consequences over product design, which focused more on creating durable objects that could be repaired, updated, reused, giving back to the disposable (Bakker et al., 2015).

Although the circular economy concept maturation has evolved substantially during the last decades, the impact of its implementation within the paradigmatic structure of capitalism, which continues to fuel consumption and resource extraction under the premise that more efficient use-oriented solutions and performance economy (Stahel, 2010) could lead to decoupling of material consumption and economic growth, is still under debate (Melles, 2021). A circular economy and society require substantial change in customer/use habits, companies' structures and regulatory frameworks. Thus individuals, groups, communities; as well as the spaces they inhabit, the objects they use, are fundamental structures to act upon. In this context, Design mediating role is key to shape the existing (and yet non-existing) materials in between those structures.

2.1. The role of design in circular economy

Design has been identified as key to support the transition to a circular economy (EMAF & Environment M.C., 2016). Within design research, a growing body of research outlines the role, suggesting useful frameworks, tools and strategies. Recent literature review identified approximately 170 strategies to support the infusion of circular design practices in companies, categorizing design tools/methods to support processes related to resources, manufacturing, distribution, use, collection and recovery (Van Kaathoven & Mizuno, 2023). Simeone et al. (2020) propose a redesign approach which could facilitate maintenance, repair, remanufacturing and material recycling. In their review, the authors frame design as an innovation process to create solutions to complex problems; and identify multiple contributions to support more circular production processes (i.e. distributed manufacturing, open design, design for value recovery); and circular consumption (i.e. consumer sustainable behavior and perception). Design contributions to sustainability have been systematized into an multi-level framework from products to socio-technical systems (Ceschin & Gaziulusoy, 2019), consolidating different design research

streams i.e. ecodesign, product service system design, sustainable business model design, transition design. Circular design has emerged as a new frontier at the intersection of circular economy and design.

2.1.1. Circular Design

While the concept of circular economy has evolved in the last 30 years, there is still a need to understand the viability of its implementation within the existing capitalist structure. So far, the circularity gap reports (Circle Economy, 2022) mentions that the progress worldwide has weakened (i.e. from 9% to 7% in the last two years). Thus, there is some urgency to expand research efforts beyond the transformation of industrial production; and break embedded patterns of a capitalist consumption culture. Morelli et al. (2024), attempted to qualify the extent to which design contributes to socio-cultural changes within circular projects, emphasizing the changing role of design towards socio- and management-oriented competencies enabling the “generation of appropriate frameworks for action rather than specific solutions” (Morelli et al., 2024). Lofthouse and Prendeville (2018) on the other hand, analyzed the positioning of human-centered design within a circular economy, emphasizing themes that influence design and drive consumer behavior i.e. value-based perspective; routines; symbolic representation and identity through consumption/non-consumption practices; and ethics. More recently, Pinho and Providência (2023), in line with other authors (Pantaleão et al., 2022; Walker & Pantaleão, 2022) propose to articulate the “aesthetic function” with the “practical function” and the “symbolic function” to change existing material and consumer culture (Pantaleão et al., 2022). Through the construction of symbolic meaning, designers are well positioned to shape culturally dominant value systems; addressing the culture of consumption where products are disposed of prematurely (for technical, functional reasons but also, for aesthetic ones, Lilley et al., 2016), requiring a shift in consumer behavior and culture (Cooper, 2017; Lofthouse & Prendeville, 2018). However, the design discourse seems to have evolved mostly within the engineering/management umbrella (Lofthouse & Prendeville, 2018), emphasizing strategies that focus on product life-extension, without much consideration to the underlying meaning and aesthetic components of products/services that take into account ecological challenges.

2.2. Meaning in Design

In design, the concept of meaning is closely connected to questions about human interaction with artifacts, and how people make sense of these experiences (Krippendorff, 2006). Meaning plays a key role in understanding interaction with artifacts (i.e. products, services, systems, interfaces) because it is underpinned by the assumption that people have agency in interacting with what makes sense to them. This becomes relevant to understand what makes people interact with artifacts, how they appropriate them in their own context and how this becomes reflected in their daily/changed practices. The role of meaning in design can include product experience (Desmet & Hekkert, 2007); as well as product semantic and design language (Providência, 2015; Verganti, 2008). The experience of meaning which unfolds during human interaction with artifacts, has a cognitive and behavioural consequence (Norman, 2005). This experience is accompanied by cognition – interpretation, association, memory retrieval (Hekkert, 2006; Norman, 2005) – and is sensitive to both individual and cultural aspects. The experience of meaning, preceded by aesthetics, enables the recognition of metaphors, assigns personality; and assesses the personal or symbolic significance of products (Desmet & Hekkert, 2007).

Additionally, meaning is also interpreted as a phenomenon connected to use. Thus, it can be characterized as a semantic quality of an artifact that leads to pragmatic and emotional interactions. Design semantics (i.e. study of signs and the way they function) includes the codes in which signs are organized depending on culture; and proposes to users a (new and/or to reinforce) systems of values/beliefs (Chandler, 2007). Designers attribute a meaning to products by using specific design language i.e. set of signs, symbols and icons (eg. style); that include design elements i.e. forms, material, texture, colour and gestalt/composition to deliver a message (Khalighy et al., 2014; Verganti, 2008). All these elements together, merge into an aesthetic that considers the socio cultural, technological context of a specific period of time.

2.3. Product Aesthetics

According to (Desmet & Hekkert, 2007; Fokkinga et al., 2020), product aesthetics concerns “... the pleasure people derive from processing the object for its own sake, source of immediate experiential pleasure in itself, and not essentially for its utility in producing something else that is either useful or pleasurable” (Berghman & Hekkert, 2017). In his study, Hekkert (2014) proposed a unified model of aesthetic appreciation, with perceptual

and cognitive principles that have been widespread and well-studied over the years (i.e. unity in variety; most advanced yet acceptable, autonomous yet connected (Blijlevens & Hekkert, 2015; Hekkert, 2014). These principles have been empirically tested in isolation and considering their joint operation and interrelatedness (Berghman & Hekkert, 2017; Blijlevens & Hekkert, 2015). However, most of the tests have so far been undertaken with existing product market products, providing more insights that seem to fuel an aesthetic of mercantile persuasion and commercial purpose (Stiegler, 2018) rather than an aesthetic that levers reflection about ecological challenges and how people operate towards those challenges. In the context of meaning, and considering aesthetics as a communicative domain which can allow to present new ways of experiencing and perceiving a place/object, the decisions made during the design project, including the aesthetic form, communicate an idea that represents a latent innovation based on the designer(s)/author(s) intention (Pinho & Providência, 2023; Providência, 2015). A product thus, can adopt a design language that delivers a message in line with current evolution of sociocultural models (i.e. users perceive the product as fashionable, stylish) conforming to existing definitions of beauty, a style that relies on accepted languages. Likewise, products can also adopt a language that delivers a message that implies a significant reinterpretation of meanings (i.e. symbolic value and/or radical innovation of meaning) (Verganti, 2008). Within the context of circularity/circular societies, however, the question of aesthetics (and its underlying meaning) is still at the emergent stage.

2.4. Research gap

The advent of the industrial celebrated the machine as a source of beauty i.e. rectilinear forms, standardization, and a lack of ornamentation (Walker & Pantaleão, 2022), prioritizing economic and mass production over ecological concerns (Pantaleão & Walker, 2021). To address these issues, several authors have proposed a new aesthetic of sustainability that integrates practical and symbolic functions considerations (Pantaleão & Walker, 2021; Walker & Pantaleão, 2022). This approach seeks to redefine material and consumer culture, aligning it with contemporary ecological paradigms. However, challenges remain in terms of consumer perception (Mugge et al., 2018) and the application of this approach within larger contexts that encompass multiple connected products and services (Vezzoli et al., 2012). While sustainability and circular economy has been included in product and industrial design curricula in some higher education institutions (Faludi et al., 2023), the discourse in design has primarily focused on creating durable objects through product-life extension strategies (e.g. Bakker et al., 2015), often adhering to industrial/machine aesthetics – making it hostage to a functionalist approach.

Emerging proposals suggest that ecological constraints can be harmonized with industrial needs by leveraging the symbolic function of ecology (Lehtinen, 2021; Pantaleão et al., 2022; Pinho & Providência, 2023). However, the development of a sustainable aesthetic is still in its early stages, and further progress is needed to overcome these challenges and integrate it into broader design contexts. Existing aesthetic experience frameworks (e.g. Desmet & Hekkert, 2007; Fokkinga et al., 2020; Hekkert, 2014), mostly tested with incremental product aesthetics, still provide limited insights for a more sustainable and ecologically-driven aesthetic. The design role has expanded to include product service systems, systemic design, and transitions towards sustainability and circularity (Ceschin & Gaziulusoy, 2019; Faludi et al., 2023). These studies position designers as facilitators, emphasizing communication and leadership skills (Faludi et al., 2023). However, there seems to be an oversight regarding the role of aesthetics experience and the semantic meaning of products within these complex systems. Design occupies a distinct position as a mediator between people, environments, and devices. While technologies and program define the project's contours, it is the authorship or "poetics" of the designer(s) that indicate their hermeneutic, ethical, and aesthetic responsibilities (Branco, 2021; Branco & Providência, 2018). Design has the power to shape culturally dominant value systems through the proposal of new design language systems and symbolic meaning (Lofthouse & Prendeville, 2018; Verganti, 2008). Repositioning these dimensions within existing design research for the circular economy is crucial to leverage its legacy and foster reflective thinking about the desired direction of the circular economy and consumption culture.

3. Methodology

To address the research gaps mentioned above and point to more holistic paths that aim to manifest the fundamental ethos of circularity, this paper proposes to develop an aesthetic and semantic exploratory inquiry into design projects that adopt a circular/sustainable ethos; and develop insights that can be useful for design to harmonise the industrial and ecological needs within the context of circularity.

3.1. Context for project selection

The projects were selected amongst design, and design and engineering master thesis dissertations, according to their relevance for the topic of circular economy and their approach to design. Due to time constraints; geographical contexts, as well as the purpose of this paper, the search was restricted to master dissertations developed within the authors university. The design ontology developed and applied within the different design educational levels (from graduation to master degree) considers the ontological contours based on a triadic model which positions design as an activity of cultural mediation, at the intersection of authorship, technology and program (Providência, 2003). This model places the intervention of design in the middle of people, functionality, needs and desires; defining its intervention as a symbolic construction of reality (Branco & Providência, 2018; Providência, 2003). Thus, it is expected to recognize these different dimensions in the design projects.

3.2. Selection criteria and analysis

Dissertations connected to the design discipline which included design projects, were considered for the aesthetic inquiry (i.e. design master; design and engineering master). First, a preliminary selection was undertaken based on the title, keywords as well as the abstracts of the open access documents of the last 5 years of production. This preliminary selection considered if the documents had any explicit connection to the topic of circular economy, circular design, sustainability, or closely related topics. Second, the documents that provided in-depth context about the process, materials, techniques, communication elements and design ethos to develop new circular products, services and/or systems were included in the analysis. Next, the projects included within the dissertations were analyzed according to multiple dimensions of existing frameworks. The main area of each project was identified along with (1) the strategies applied for a circular economy i.e. following the example of Morelli et al. (forthcoming); (2) aesthetic and semantic aspects; (4) means of production and technologies; (3) potential human impact (following Fokkinga et al., 2020 framework).

4. Results

This section focuses on providing a descriptive analysis of the results obtained from the selected cases (Table 1; Figure 1). As previously mentioned, the cases were analysed following existing frameworks, relating the ontological contours of design (program, technology, and aesthetics/semantics) with circular economy and its potential human impact. The cases selected encompass multiple areas of product design i.e. accessories, fashion, furniture, kitchenware and lighting (Figure 1). The projects followed product design processes, going through benchmarking exercises, market analysis; material exploration and testing (mostly considering material behaviour when transformed or processed e.g. plastic moulding), sketching, design refinement, rendering; and most of the cases presented high-fidelity material prototypes.

5. Discussion

While the previous section aimed to provide a description of all the cases included in this study, this section focuses on (1) exploring and reflecting upon the aesthetic role of design within circular projects, developed within the scope of circular design; (2) reflecting on the potential of these projects to trigger socio-cultural change, and diffusion of more circular practice. Next, to support cross-case analysis, a matrix was developed (Figure 2). The matrix axes emerged from the analysis of the cases and proved to be useful to make some comparisons between project components that are connected to material function, meaning and sustainable aesthetics. The projects were organized within the four quadrants of the matrix (Figure 2).

5.1. Explicit and silent sustainable aesthetics

Most cases demonstrate what can be defined as an “explicit” sustainable aesthetics (Q1, Q2), that is, artifacts that adopt a design language (i.e. forms, materials, texture and composition) that provide compelling cues that indicate a contribution towards sustainability. For instance, P3, P4, P7 are projects with uneven material textures on the surface resulting from the production processes, plastic melting and compression; and whose colours are

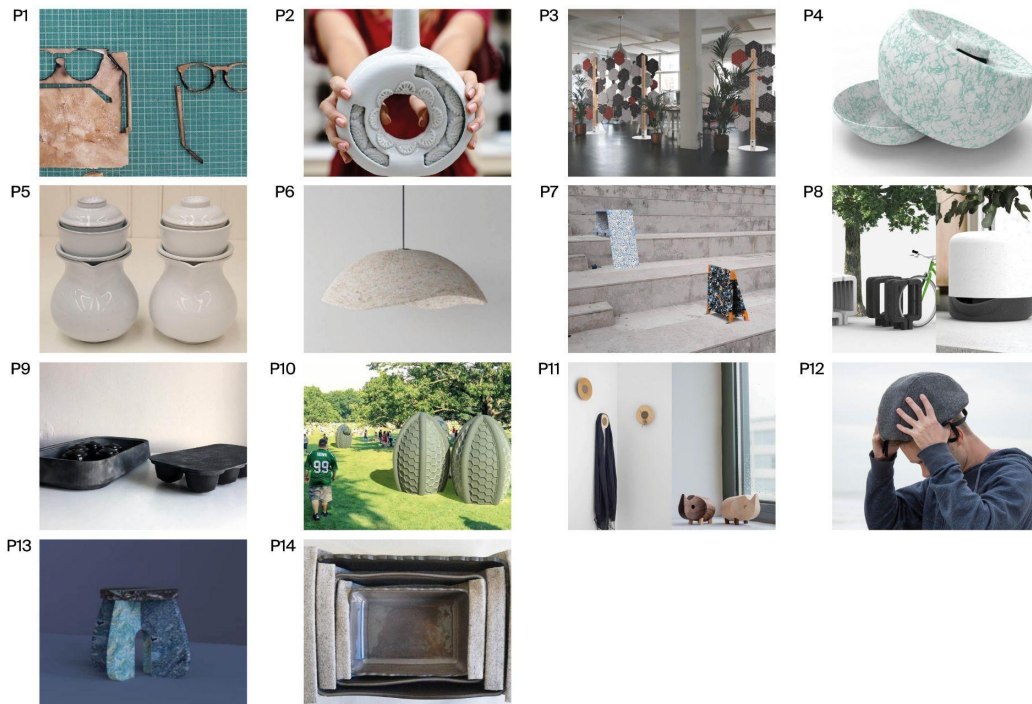


Fig. 1. Representative images of each case: P1 (Faúlha, 2021); P2 (Agostinho, 2019); P3 (Silva, 2022); P4 (Costa, 2019); P5 (Portela, 2019); P6 (M. Lima, 2020); P7 (Oliveira, 2020); P8 (Marques, 2019); P9 (Jorge, 2019); P10 (Melo, 2018); P11 (Taipina, 2019); P12 (Mingote, 2023); P13 (Pinto, 2022); P14 (Cordeiro, 2022).

not equal within the same batch of production. Shapes are simple, with no intricate surfaces, closely aligning with forms that allude to minimalism. Cases P2 and P5, also included within the same category, use ceramic pastes through 3D printing and preserve imperfections of the shape, alluding to traditional values of things made “by hand”, with care.

On the other hand, “silent” sustainable aesthetics projects (Q3, Q4) are composed of artefacts that either use materials that come from renewable sources (e.g. cork; wood, wool); and/or integrate more efficient production processes that are not necessarily reflected in the design language. For instance, cases P8 or P11 are projects that can fit well within existing industrial aesthetics. There is greater incorporation of distributed production technologies (3D) focused on material savings, the possibility of scaling the quantity of product and thinking at the production and engineering level of materials.

5.2. Form follows material function

The other axis emerged from the analysis of the cases. Half of the cases fit within the category of “form follows material function” (Q1, Q3), meaning that the design of the form is conditioned by material qualities, which in turn defines the function and form of the artefact. These artefacts closely align with the premises of material-driven design (Karana et al., 2015), circularity is latent in the surrounding processes and formal optimization. Several projects, such as P1, P4, P7, P13 started from the exploration of existing waste materials in a specific industrial context (e.g. wood waste); or in specific environmental contexts (e.g. waste within the ocean) with the mission of reducing the quantity of materials that goes to landfills. For instance, P1 intended to use surfboard waste, thus the material behaviour to existing transformation processes established the guidelines for product development. The final product (i.e. glasses made from surfboard waste) were made considering the surfing culture, keeping materials usage within similar social circles. P9 used coffee capsules to develop a product with a new purpose by maintaining previously existing shape (capsule) and partially transforming the capsules into a cuvette that protects mushroom growth. In those cases, the material function overlays aesthetic function since the intention of the design is initially dependent on material availability and characteristics.

Table 1: Results obtained from the selected cases

#	short description	program /utility, performance	technology /production means	aesthetics /symbolic meaning	circular economy	human impact /behavior, experience, knowledge, attitude
P1	revalue waste from surfboards in a closed loop	sunglasses made from recycling plastics of surfboards; practical and versatile glasses, can be for users beyond surfing community	heating, compression and molding of recycled plastics; assembly with no glue	preservation of material imperfection, color and texture of its recycling process conveys the transparency of its design, true and non-alienating	recycling, refurbishing	material resources and products from/for the same community of users; can be useful to create classes of recycled products; can awaken more environmentally friendly consumption choices through the community
P2	porcelain vase set developed with ceramic 3D printing	3D printing bridging craftsmanship and production. Inspiration from traditional portuguese products with complex shapes	robocast 3D printing allowing the production of more complex structures and traditional patterns	combination of traditional and contemporary values, new materiality and tech, preserving the imperfections of the piece and the economy of the material	reduction; optimization of material usage	preservation of object because of its unique pattern and "portugality"; involvement in artisanal knowledge and techniques and connection with local crafts
P3	office separation system from wasted plastics	revalue wasted plastics, mechanical performance evaluation of combination of plastics; modular and easily repaired product; versatile separation objects	compression and molding of recycled plastics	hexagonal geometry, visibility of materials used, preservation of texture and pattern from the recycling process	recycling, avoid creating waste from plastics	promote familiar imagery of circular plastics and sustainable aesthetics; improve coworking spaces quality
P4	money box developed with plastic waste	piggy bank to store money and keys	rotational molding, recycled plastics, production with a minimum waste	maintain material appearance and textures, every produced pieces have diferente textures; artefact with alternative material (resignification)	recycling	promotes plastic recycling
P5	tea service designed using eco-stoneware	investigation into the identity and opportunity of contemporary design production, in an industrial context, reflected in the development of a tea service with eco material	paste formation and cooking typically used in this type of ceramic product	traditional Japanese-inspired design language, using ecological material	reduction; optimization of material usage	preservation of cultural heritage combined with sustainable attitudes promotion of stoneware cultural practices adapted to social reality
P6	suspended lamp developed using waste	biodegradable lighting products through the selection of materials with better circular performance	molding; material selection study with the best circular impact (Mycocomposite)	material economy and use of local materials, biomimetic inspiration, preserves texture, color and natural pattern of the material used, referring to principles of simplicity, truth	recycling	reinforce simplicity imagery, approximates sustainable aesthetics from existing aesthetics
P7	versatile public space objects to support enjoying meals and leisure time within aveiro uni campus	urban objects that support enjoying meals in the campus, while considering existing urban furniture	collection of domestic plastic; mechanical shredding, molding and pressing into pallets; mechanical assembly	functionalist aesthetics, application of straight lines, simple and regular shapes, preservation of the textures and colors of the paste; logo/pallet	upcycling	promote familiar imagery of circular plastics and sustainable aesthetics; expands options for social events

				colours defined according to UA design language		
P8	vase with self-loading system and urban furniture for bicycles developed using marine plastics	pot with self-watering system urban furniture; partnership with waste management organizations	3D printing with plastic waste filament collected from sea and domestic plastic waste; low tech production	preservation of imperfection, of apparent material; uniqueness derived from the 3D production process; urban furniture presents a relationship with constructivist aesthetics	recycling, refurbish processes	preservation of the marine ecosystem, reduction of plastic contamination; awareness of preservation of water resources
P9	"cuvette" produced from coffee capsules for plant growth	development of a kit to grow mushrooms from reuse of coffee capsules	3D printing of recycled plastics from capsules	maintaining shape, color and material texture as a way of alluding to preservation	repurpose, recycle	promotes capsule recycling behavior; raises awareness of the extinction of natural resources
P10	sustainable hygiene module for festivals with biomimetic inspirations	hygiene module to use outside, in festivals, enabling participants to take quick showers; modular, quick to assemble/disassemble	extrusion of insuflable structure in PVC and the application of solar textiles; has water filtration system and a luggage compartment	geometric biomimicry	reuse, multiple cycles of use	improves experience and accessibility at events, accessible, easy to use hygienic options; which are more environmentally friendly
P11	valorization of waste produced from the fabrication of wood furniture, and development of decorative/utilitarian accessories, complementary to existing products of the company	development of small decorative artefacts serving as a complement to the main products following the premises of competing markets (rhino and hanger); increase awareness of environmental destruction	carpentry equipment typically used in fabrication of wood waste furniture	playful symbolic function; the use of a unique material; the hanger, presents a clean aesthetic language representing the possibilities of "good design"	recycling	promotes a more efficiently industry with no waste; encourages upcycling remains of wood and tissues into new products
P12	design lower carbon-emission helmet with design for disassembly principles; and promote the adoption of safer riding micro-mobility habits (bike/scotter);	protection helmet, foldable for easier storage; elimination of glue and EPs replacement for more sustainable production; and easy disassembly	usage of expanded cork with no glue assembly for protection purpose; outer layer made with burel, a traditional material	functionalist aesthetics; casual appearance, cultural symbiosis through usage of local materials	enables seamless disassembly, with no glue, can substitute parts	support for safer rides within micromobility urban contexts; contributes for more efficient and sustainable cities
P13	design of a piece of furniture from the combination of textile waste and wood.	ecological solution in the concession of furniture, used as raw material for waste generated in the textile and wood industries.	textiles and wood wastes; Molding the past of PP e MDF wastes and pressing and cutting	maintenance of visible material, roughness and color; modularity.	rethink; recycle	circular attitude in materials + modular design
P14	design of a set of ovenware inspired from portuguese tradition and territory, combining local materials	combination of burel and ecogres materials, burel used due to resistance to high temperature and waterproof handles; separated products	usage of subproduct; 3D printing with ceramic paste, mold development for bigger pieces; cooking and drying the ceramic; glazing in some parts	brutalist aesthetics, maintaining imperfection, using subproduct materials; forms adopt a handcrafted appearance, semantics connected to the sea and Portuguese territorial features	use of subproduct to design new objects; update	reconnection of user with local materials through cooking; lever tradition through the kitchen

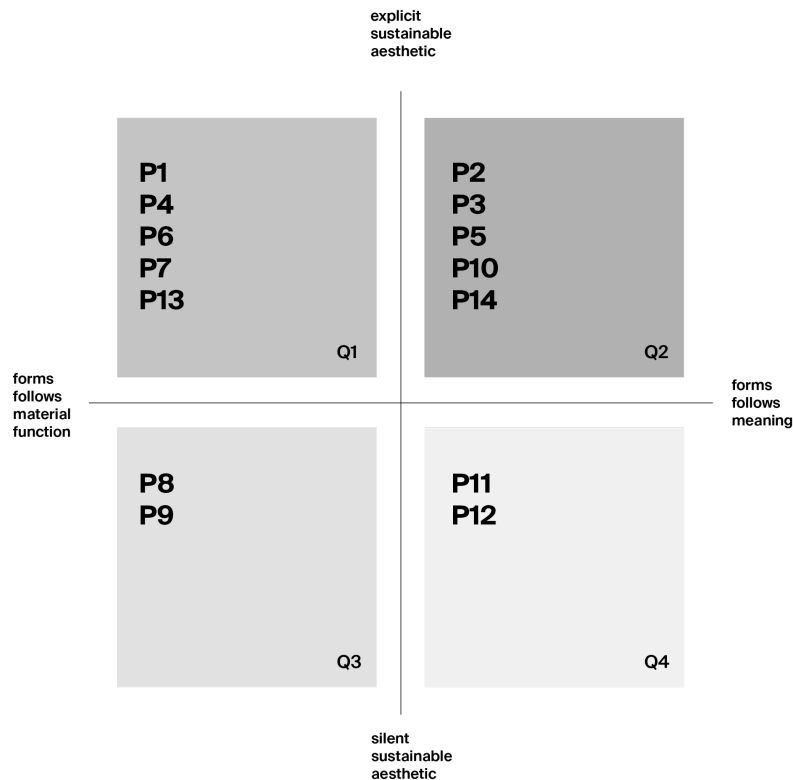


Fig. 2. Conceptual analysis matrix

5.3. Form follows symbolic meaning

At the other hand of the spectrum, projects such as P2, P3, P5, P10, P11, P12, P14 start with a design that assumes a role of attributing meaning to the object (Q2, Q4), using form as a promoter of a certain idea and/or metaphor i.e. sustainability, protection of the ocean and/or animals, local culture. For instance, P2 attributes symbolic meaning, using 3D printing technology to reinterpret traditional patterns and preserving materials. P10 uses a biomimicry approach to develop a product that enables taking showers in public spaces. P12 aimed to promote helmet use within micro mobility contexts, developing a helmet that fits within an urban style and culture. The helmet uses local and renewable materials; can be used multiple times even after one fall because of the properties of the cork; and enables the user to change the exterior layer. P14 is a set of ovenware whose shape was inspired by the ocean waves and characteristics of the Portuguese territory, using and combining local materials (i.e. burel). In those cases, the aesthetic form is defined based on the symbol; and iteratively refined alongside material exploration and experimentation.

5.4. Contributions of circular design and aesthetics to circular economy

Despite showcasing circular design components, the projects are mostly stand-alone products, providing limited perspectives regarding the integration of the object into circular value chains, guaranteeing its valorisation in the circular economic cycle. Moreover, considerations regarding the infusion of services and/or other IoT-enabled features which could support a more efficient, circular and scalable solution, to meso levels of intervention, are also not thoroughly present within these projects. While some projects, such as P10, do consider logistic issues in product development enabling the optimisation of transportation processes, as well as assembly/disassembly of components; other project consider the origin of the materials (e.g. waste from ocean), but are unclear regarding the post-life use of the product. P8 also integrates some service and business components, considering the inclusion of different stakeholders (e.g. partnership with municipality and local waste management companies to collect ocean waste), without, however, providing much detail on how they will be included within the solution. Moreover, most projects remain in lower levels of circular economy i.e. recycling, refurbishing, repurposing, optimising material usage; upcycling, following principles found in existing circular design approaches (e.g. Bakker et al., 2015). When considering the human impact (Fokkinga et al., 2019 i.e., behaviour,

knowledge, attitude, experience) within explicit sustainable aesthetics-oriented projects, the analysis concluded that most aim to promote a familiar imagery of sustainability and/or traditional crafts (i.e. uneven surfaces/shapes; multiple colours, no-repetitive patterns and different textures) e.g. P2, P7, P14. Projects that emphasise a more silent sustainable aesthetics, tend to aim at influencing behaviour (enable/support recycling processes; reuse of products/materials; maintaining the product within multiple use cycles). These objectives are not exclusive to silent/explicit sustainable aesthetics, having some intersections; and demonstrate the mediating role of design, as the bridge between behaviour and thought.

5.5. Potential for human impact

Going back to the argument that design can be a manifestation of an aesthetic intention (Ortega y Gasset, 2000) the use of different configurations, forms, textures and/or colours (identified as an explicit sustainable aesthetics in this study), can contribute to challenge perceptions and awake “human numbness” towards a proposal of a new world, opening space for a dialogue about economy, society, and the culture yet to become. However, within the scope of the cases available, the potential for human impact and scalability through aesthetics was found to be limited and/or often incomplete. In the context of master dissertation theses, design projects are typically developed within a relatively short time frame, ranging from several months to one year. During this period, students engage in learning about the design process and its connections to various disciplines. The shift to Bolonha has resulted in a compressed learning curve, reducing the time available for exploring, iterating, and consolidating the design's intention.

The industrial context and society is changing, drifting in-between scenarios of what could be a more sustainable future. These futures have so far strongly emphasised the origin of resources and second-hand materials. The knowledge about the qualities of these non-virgin materials is still developing and their availability also requires logistic reconfiguration. Furthermore, the technologies and processes used to manipulate these materials have encountered new challenges. Previously, these processes would yield predictable outcomes, but with the utilization of mixed plastics as an example, it is now apparent that they possess different technical capacities compared to virgin plastics - compromising the “predictable” final form. The design projects herein included, often tend to adopt a functionalist perspective, where the product's function is primarily defined based on the availability and characteristics of materials, which can limit the exploration of alternative design. Additionally, the time constraints may lead to a focus on what is currently feasible and familiar in terms of aesthetics. In about half the cases, the aesthetic aspects of the project emerged without a clear and intentional design direction which can hinder the development of a cohesive and purposeful aesthetic. If “forms communicate and their aesthetics can (...) enable the conception of a new moral idea that puts forward the sublimated society, submissive to material consumption” (Pinho and Providência, 2023), then knowledge about the means to make these forms and design intentions come true need to be further consolidated.

6. Conclusions, limitations and future studies

This paper aimed to explore the aesthetic role of design within the discourse of circular economy; and its potential role to reach human impact. To reach these goals, the paper develops a conceptual matrix that intersects sustainable aesthetics with material function and symbolic meaning, attaching these dimensions to 14 different circular design projects developed within master dissertations. The matrix and analysis contribute to consolidate a more balanced approach to circular design, presenting a spectrum of approaches that intertwine material function, meaning and aesthetics. This study also presents limitations. First, despite providing a full description of the process, and enabling cross-case analysis, the set of cases is based on master dissertation projects. These cases enabled the development of a conceptual matrix, which could be further consolidated with more robust projects ; Second, most of the cases are mostly product-oriented i.e. accessories, fashion, furniture, kitchenware and lighting. Expanding the analysis to other design disciplines as well as other levels of complexity, including product-service systems, is paramount to explore the role of aesthetic and meaning within these solutions. Overall, the study advances design research, contributing specifically to reflect on the role of aesthetics and meaning within the discourse of circular design and circular economy.

7. References

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