Enhancing Environmental Sustainability in AI-Infused objects Ecosystems through User Experience: Expert validation and Insights[1]

Alice Paracolli [a*] | Venanzio Arquilla [a]

[a] Politecnico di Milano, Department of Design: Milan, Italy.
* Corresponding author: alice.paracolli@polimi.it

ABSTRACT

The study highlights the need and challenges of assessing the environmental sustainability of AI-infused Objects forming product-service ecosystems through the design lens. Through literature review, it aims to heighten designers' awareness of the environmental impact linked with this technology and facilitating decision-making through impact evaluation. The contribution for designers initiates by outlining three distinct components of AI-Infused Objects analysis, which are physical, digital, and usage. It then proceeds to identify the environmental impacts connected to each component. The study concludes by incorporating insights from field experts interviews aimed to understand how the design perspective can effectively address and overcome the impacts posed by the technology.

Keywords: Artificial Intelligence, Design, Service Design, Sustainability, User Experience

INTRODUCTION

The ecosystems of AI-infused objects have driven a transformation in everyday products, incorporating electronic components and establishing connectivity through the Internet and mobile networks, analysing data from the environment and users to generate user-specific feedback (ITU, 2020). Notable examples include Amazon's Alexa, a gateway to their services, and smartwatches that assist users throughout the day, providing health-related feedback. The effect of digitization on value creation processes has been explored in service research (D'Emidio et al., 2015; Toivonen & Saari, 2019).

Within this changing landscape, designer's role is transforming, encompassing changes in both design process and environmental considerations due to the rising numbers of AI-infused objects underscore the need to consider their environmental impact (CISCO, 2020). This text identifies impacts tied to each component of AI-Infused Object Ecosystems "physical", "digital" and "usage" components. Prior studies have separately examined the impact of product-service (Vezzoli et al., 2017), lifecycle assessment for their "intelligence" (Ligozat, 2022), and user-related effects (Stermieri, 2023). Yet, no research from a design standpoint integrates these aspects within AI-infused Object Ecosystems, especially through User Experience lens

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(UX). UX's potential application across the process should consider sustainability as a central stakeholder during the whole project.

To explore the environmental impacts generated by AI-infused objects, the literature review followed the keywords: “AI” “environmental impacts”, “human behaviour” “evaluation”. The analysed studies came mainly from engineering and sustainability. The aim was to bring awareness to the design world of the state of the art of the complex dimension of sustainability in AI-infused Objects. The literature review insights were discussed through interviews with experts of the field, to validate the data acquired and further elaborate on the role of the UX designer for the sustainability dimension of AI-infused objects.

1. AI-INFUSED OBJECTS: UNVEILING THEIR SERVICE PROPOSITION

AI-infused objects are smart objects that incorporate artificial intelligence to enhance their functionality (Vitali, 2022). They can include devices like smart speakers and wearable gadgets, such as smartwatches. These objects are cyber-physical, physical objects with a digital representation (Agrò, 2018). They are networked and connect to other products using various wired and wireless communication technologies, forming an ecosystem of touchpoints with a ‘digital soul’ (Abramovici, 2014; Greengard, 2015). They are designed to collect and analyse data using AI algorithms, aiming to provide users with improved experiences and support in various situations. Their 'intelligence', understood as the ability to handle information or make decisions, can be located not necessarily at the device level (Meyer et al., 2009). AI-infused objects exhibit autonomous and proactive behaviour, giving the user ad hoc feedback and supporting them in activities with or without their awareness, e.g. autonomously changing the room temperature to make it more comfortable. They can continuously monitor their state and environment and have sensing capabilities (Vitali, 2022). They can often learn from experience and infer high-level patterns and events from the data (e.g. understand a specific user's preferences). This allows intelligent products to show forms of awareness and evolve their performance over time (Spallazzo, 2022). Having a method capable of evaluating the impacts the service supported by ecosystem of AI-infused objects at a systemic level is fundamental because its outcome becomes a tool for value creation and a driver for product innovation, identifying areas for project improvement (Foglieni, 2007). In a previous study, the authors Arquilla & Paracolli (2023) identify the three primary components of the ecosystem, each illustrated through the example of a smart refrigerator:

- **Physical Components**: the tangible parts of the object, including the physical touchpoints through which users interact. In the smart refrigerator, the refrigerator itself. Additionally, the related intelligent components such as screens, touchscreens, speakers, and sensors.
- **Digital Components**: everything necessary for an AI-infused object to exhibit "intelligent" capabilities. In a smart fridge, it involves connectivity requirements to link with the internet and other objects. Moreover, it entails the AI's computational capacity, e.g. data processing during object inference.
- **Usage Component**: involves the direct user interactions with the smart fridge, like how often it's used per hour. Furthermore, it considers the broader impact originating from alterations in user behaviour due to the adoption of a specific AI-infused Object

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like the smart refrigerator. This encompasses changes in users' daily routines as a result of interacting with the object.

The physical component is represented by the refrigerator itself, equipped with sensors that capture valuable information. The collected data is transmitted through communication technology and sent to the cloud, where it becomes an essential element for creating a customized service. This service usually materializes through an app/screen, becoming the primary point of contact with the user alongside the product itself, turning it into a smart object.

But what functions can this refrigerator perform? Beyond its traditional role, it can suggest diets, recipes, products to purchase, and expiration dates, alerting when certain items need replacement and providing valuable information. All of these functionalities are highly useful to the user, but each of them generates specific impacts. These impacts can vary in nature and must be carefully analysed and correlated.

In order to analyse the environmental impact of AI-Infused Objects we need to consider all the three components.

2. METHODOLOGIES AND VARIANTS TO ASSESS SUSTAINABILITY OF PHYSICAL COMPONENT OF AI-INFUSED OBJECTS

The Life Cycle Assessment (LCA) is the most used methodology to assess the environmental impacts of a product, process, or service over its entire life cycle (Ilgin et al., 2010). LCA is an ideal methodology to analyze the *physical component* because it comprehensively evaluates the environmental impact of an object's tangible parts. According to ISO 14040/44, LCA involves defining goals, conducting inventory analysis, assessing impacts, and interpreting results. System boundaries and functional units are established for comparative evaluation (ISO, 2006). Integrating environmental requirements into the design of a service means dealing with increased complexity, a large amount of information and relationships with stakeholders from different disciplines (Vezzoli, 2017). This is because Design needs to adopt a systemic approach to all product life cycle phases. Thereby, designers can reduce material inputs, energy consumption, emissions, and waste impact, they contribute to both reduce quantitatively the impact generated by the service and improve qualitatively the service for the user. Two primary approaches for lifecycle environmental impact assessment are attributional LCA (ALCA) and consequential LCA (CLCA). ALCA aims to quantify a product's or service's environmental impacts using average processes. Emissions are evenly allocated across processes. Conversely, CLCA employs marginal processes focusing on the broader system-wide effects resulting from the implementation of a specific product or service. (Ekvall, 2019). Both perspectives are crucial for sustainable service development even though current practices often emphasize only direct attribution impacts, additionally overlook social, economic, and AI-related impacts when assessing a service's LCA.

Sustainable design, which originally targeted reduced environmental impact, has evolved to require a thorough focus on the three dimensions of sustainability: environmental, economic, and social (Larsen et al., 2022). Despite this shift, existing literature falls short in systematically addressing technologically integrated objects. Often, studies emphasize only a single aspect. Furthermore, there's growing attention to understand the typically overlooked aspect of product usage details; advances in telematics enable real-time usage data acquisition but challenges in collecting relevant data remain (Kim et al., 2020). While resource optimization is established in sustainable design, integrating data from usage analysis, and lifespan management emerge as research frontiers. Further, defining clear system boundaries becomes crucial to enhance the reliability of environmental impact assessments, particularly for complex systems such as AI-Infused Objects (Kim et al., 2020).

Although Kloepffer introduced life cycle sustainability assessment (LCSA) in 2008, practical implementation remains limited. This approach encompasses social, economic, and environmental dimensions and integrates Social Life Cycle Assessment (S-LCA) and Life Cycle Cost (LCC). The former, S-LCA, evaluates social aspects of services, their positive and negative impacts across all life cycle stages, the UNEP Guidelines are widely used (Tokede & Traverso, 2020). Life Cycle Sustainable Assessment (LCSA) offers a holistic view in decision-making, considering social, economic, and environmental impacts. LCSA reveals instances where the Circular Economy's attention to specific resource 'circularity' might miss the bigger picture, and where a broader sustainability perspective is needed to assess specific circular strategies (Peña et al., 2020).

While often applied in engineering, these evaluations are underutilized and require more design-oriented exploration to translate LCSA insights into practical solutions.

3. THE IMPACT OF THE DIGITAL COMPONENT IN AI-INFUSED OBJECT

The digital component of AI-infused objects yields both direct and indirect environmental impacts. *Direct impacts* are primarily driven by the energy needed and material flow to sustain AI (life cycle) and technology communication. For instance, an AI system managing building lights is deemed sustainable, yet the system's inherent ability to adjust based on user habits can surpass the occasional human error of leaving lights on. According to the belief that 'bigger is better': the systematic collection of more data and the use of more computation cycles until a better result is achieved has led to a sharp increase in energy consumption (Crawford, 2021). Since 2012, the amount of computation used to train a single AI model has increased tenfold yearly: developers 'repeatedly find ways to use multiple chips in parallel and are willing to pay the economic cost' (Cook et al., 2017).

Indirect impacts encompass positive (enablement) or negative (rebound) consequences linked to new services or products (Coroamă et al., 2020; Wohlschlager et al., 2021). These effects are relevant at both the household level, where they involve changes in consumption patterns, and at the system level, where they can impact on the integration of renewable energies. In the ICT realm, addressing rebound effects requires cross-disciplinary approaches, such as behavioral research (Kaack et al., 2022). With regard to smart meters and similar adaptable services, the novelty of the analysed use case and the scarcity of empirical data impede the quantification of rebound effects. This possibility is known in the scientific community, where numerous studies have assessed the impact of AI, primarily within engineering. Yet, these studies are scarcely shared with the designers responsible for adapting technology to be used. AI literature primarily addresses limited direct impacts but still neglecting production, end-of-life, and indirect effects. in Wu et al. (2022) and Gupta et al. (2022) criticize previous studies' methodological limitations, concentrated on the utilization phase. Lacoste et al. (2019) and Kaack et al. (2022) delve into AI service carbon emissions, offering a broader view of direct carbon footprint impacts. Kaack et al. (2022) also advocate considering indirect impacts, like behavioural or social changes due to AI. Ligozat et al. (2022) reveal underestimation in current AI service environmental assessment. AI for Green mainly addresses a small portion of direct environmental impacts, also due to narratives about dematerialization that have proven false (Ligozat et al., 2022). AI's greenhouse gas emissions emphasize electricity consumption, overshadowing material flows which are gaining attention (Wu et al., 2022 & Gupta et al., 2022).

Indirect impact of technology communication resides also in the human labour required to keep alive the infrastructure, data's societal role, and the resource-intensive nature of infrastructure construction deserve attention (Crawford, 2018, 2021). Specifically for AI, training algorithms include often dehumanizes human labor operation, data usage might be misused and generate biases. In this context, designers play a pivotal role in considering where and how AI is applied.

3.1. Impact of Usage Component

The impact generated by the usage component is strictly linked to the domestication process, how its adoption could modify our society, leading to new environmental impacts. These kinds of effects could be Consider 'rebound' as an example. This term relates to how product consumption responds to price shifts. All the efficiency and substitution benefits from ICT will encounter some degree of direct rebound. Shehabi (2017) offers an illustrative instance of the dematerialization paradigm: streaming videos, while energy-efficient compared to cinema visits or DVD rentals, can lead to increased movie-watching due to convenience, ultimately offsetting efficiency gains. Shehabi (2017) emphasizes that direct rebound impact is limited only by saturation (i.e. time or users interests). Moreover, indirect rebound considers the effects of the time or money saved through ICT efficiency or substitution, e.g. opting for home streaming over cinema outings leaves room for more activities or purchases, potentially affecting environmental impact differently than the original choice. Methods such as survey (Phol et al. 2021), and scenarios (Guerin, 2021) have been used to identify the impacts, then evaluated with LCA assessment. However, these effects are complicated to quantify, as they are connected to the socio-economic change induced by the type of ICT end-uses (Pohl & Hilty, 2019).

4. THE ROLE OF USER EXPERIENCE FOR SUSTAINABILITY

Kerr (2015) states that User Experience is a lens, a perspective through which one can observe a product, service or anything else. It is also the point of view through which users perceive the designer intention. User Experience can also be a means of evaluating a product and service by analysing how the user interacts with it (Berni et al, 2023). This dual functionality gives UX a systemic and prospective view. UX designers consider the interaction with an object from the user's perspective throughout the design process, in contrast to employing "top-down" strategies that often emphasize technical solutions and overlook true stakeholder needs, thereby embracing a more holistic design approach (Norman, 1988). The remarkable aspect of UX is that the process is continuously iterative, which promotes constant change and updating of the product, even after it has been sold or released: in digital products, software is updated through the 'cloud' or the Internet (Gothelf & Seiden, 2021). This dynamic nature guide designers in consistently enhancing the user's experience.

Verganti and Norman (2014) emphasize that the iterative cycle of UX research and updates consistently brings technology solutions closer to user and stakeholder interests, leading to valuable incremental innovations. If sustainability is treated as a stakeholder, it implies our capacity to foster incrementally sustainable innovations. For instance, when users interact with AI-infused objects, such interactions generate environmental impact. As designers, we must account for the ecological footprint of our products and their utilization. Monteiro (2019 p.18) reminds us that "A designer values impact over form: We need to fear the consequences of our work more than we love the geniality of our ideas... In the end, we must judge the value of our work based on impact."

The impact stemming from UX in AI-infused objects can be direct, arising from user interaction during the use of the service itself, such as energy consumption during specific interactions (inference energy, Ligozat 2022), or indirect, generated by changes introduced by the service in the user's life (Ries et al., 2023). The impact of user interaction with digital products has been explored in Sustainable Interaction Design (Remy, 2018), which divides the field into Sustainability in Design and Sustainability through Design. The former aims to design products with minimal impact (both physically and during use) (Belvis, 2007), while the latter aims to support sustainable lifestyles through products that drive changes in people's habits or raise awareness about sustainability issues (Remy, 2018). However, these two perspectives might benefit from a comprehensive vision that the lens of UX could provide, through analyzing user context and needs. Hence, a shift in perspective is required: it's not enough to design highly efficient or minimally impactful products or objects that guide users towards more sustainable behaviour. As highlighted by Hssenzahl (2021), "we cannot solve the problem of resource consumption and social aspects of sustainability by solely focusing on efficiency", but "technology must primarily be a positive experience for users." This implies that if an experience is highly efficient (and perhaps sustainable) but insignificant for the user, the designer would have created a futile product that remains unused. Artefacts must be useful and adaptable to the user's context, and this is where UX plays a pivotal role. Hence, firstly, the object must be useful and possess hedonic characteristics. Subsequently, it's imperative to determine the least impactful approach to creating this specific experience and then, through this experience, we can guide the user towards more sustainable behaviour, whether conscious or unconscious. This concept also applies to the design of AI-infused objects, which should be regarded as agents promoting sustainability. Technology should be viewed as an intermediary, amplifying, determinant, and promotive of human behaviour and its impacts (Midden et al., 2007).

5. EXPERTS POINT OF VIEW

5.1. Interview Methodology

The authors held 21 semi conducted interview with experts from the field to validate both the existing literature analysis and to gain an understanding of practical implementation with experts.

The cohort was carefully selected, all participants have +5 years of experience in relevant fields. Among the participants, eight were Professional Designer or Experienced academics (pD), six were ethicists in IoT enterprise or academics (pT), and seven were from the IoT Design and Development department of a multinational enterprise (pI) (Table 1).

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Each interview (1h45min) was divided into two sections. The first explored the relationship between sustainability and AI, the second delved into the role of designers in fostering the dimension of sustainability in AI-Infused Objects. The second part included a 10-minute presentation by the author, introducing the research and providing contextual definitions for UX, environmental impacts, and components of AI-infused Objects, supported by visuals on Miro board (appendix A-B-C-D).

Interviews were recorded using Teams as per prior agreement. The researcher reviewed all interviews then coded and categorized data using thematic analysis. The Miro platform was employed for affinity diagrams in the analysis, facilitating the identification of thematic patterns.

The interviews served to pinpoint potential change agents, making them not just visible but central to the process. This approach aimed to create a reflective space for mutual learning between participants and researchers, aligned with a transformative learning experience (Nielsen & Lyhne, 2016).

Table 1: interview participants

Code	Group	Role	Description	Years of experience
pD1	Design	Academic	Service Designer, Sustainability expert	+20
pD2	Design	Academic	Product Designer, UX Designer	+5
pD3	Design	Academic, Business	Product Design for the Climate Era	+5
pD4	Design	Academic, Business	Academic, Service Design Expert	+15
pD5	Design	Academic, Business	Academic, Corporate Sustainability Management	+5
pD6	Design	Academic	Academic, Industrial Design and Service Designer	+5
pD7	Design	Academic, Business	Design Futures Lead	+15
pD8	Design	Academic, Business	Executive Design Director	+20
pT1	Philosophy of Technology	Academic	Ethics, AI and Sustainability Expert	+5
pT2	Philosophy of Technology	Academic, Business	Ethics, AI and Sustainability Expert	+10
pT3	Philosophy of Technology	Academic	Persuasive Technology for Sustainability	+10
pT4	Philosophy of Technology	Business	IT Sustainability Lead	+5
pT5	Philosophy of Technology	Academic, Business	Ethics, AI and Sustainability Expert	+20
pT6	Philosophy of Technology	Academic, Business	Ethics, AI and Sustainability Expert	+5
pI1	IoT Design and Development department	Business	Sustainable technologist expert	+10
pI2	IoT Design and Development department	Business	Design Associate Director	+20
pI3	IoT Design and Development department	Business	Sustainable technologist expert	+5
pI4	IoT Design and Development department	Business	Senior UX and Service Designer	+10

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Code	Group	Role	Description	Years of experience
pI5	IoT Design and Development department	Business	AI Expert, Leader of AI/NLP Practice	+10
pI6	IoT Design and Development department	Business	AI Engineer	+5
pI7	IoT Design and Development department	Business	Service Designer and researcher	+15

5.2. Findings

We categorized our findings into three main themes: the current integration of sustainability in the design and development of AI-infused objects, the role of designers in ensuring sustainability in AI-infused objects, and the designers' requirements to advance the sustainability dimension of these objects. These themes are interconnected, and some aspects span across all three.

A notable observation was that the AI component was not distinctly treated from other IT systems. Participants across all three categories used "technology" and "artificial intelligence" interchangeably when discussing design, processes, and regulatory aspects that influence the sustainability of AI-infused Objects. This convergence is intriguing, as the authors also identified analogous patterns in the literature involving contributions beyond the realm of computer science related to this subject.

Furthermore, a common thread among diverse participants was the recognition of the necessity for cross-disciplinary collaboration to comprehensively address the sustainability aspect.

5.3. The current integration of sustainability in the design and development of AI-infused objects

During the development phase of IoT, the environmental impact of technological solutions is rarely taken into consideration. Usually, the focus is on the efficiency of the solution, which may sometimes align with being less energy consuming. While the awareness of environmental sustainability is expressed but "it is rarely a delivery requirement… however, economic and environmental sustainability share common ground, such as lighter algorithms" (pI.5). The developing process is mainly technology-driven, and the details of the usage context of the solution aren't considered. PI6 states that they start by inventing an algorithm or sequences that can produce something interesting from a technological perspective, then "we hand it over to business people and designers who make it marketable and useful, building an idea around it". Clearly, later on it needs to be readapted to follow all project specifications and make it to the market.

On the other hand, designers state that when the project is "design-push", even if it starts from an already existing technological solution, sustainability is one of the innovation drivers. Nonetheless, the central objective is understanding customer desires and how to support users with what the customer requests. At the project's initial phase, service designers conduct research and arrive at concepts that consistently reference sustainability impacts, such as comparative life cycle assessments of objects or less energy-consuming interfaces, but the strategy to make the product sustainable come from inner intuition of designer. However, often during the project's implementation phase, when the concept is handed over to UX and developers, it loses “its systemic perspective, and its realization becomes more vertical, focusing on single touchpoints” (pI.2). This leads sustainability to be forgotten. In general, academic designers suggest that service design, has a primarily strategic role in terms of concepts to capture clients attention. This involves research and collaborative activities such as workshops and user research and come up with solutions sometimes distant from what can be feasibly developed. Establishing more continuity by creating feasible concepts with detailed specifications for execution during development and design could provide more consistency (pD.4).

From the perspective of pTs, sustainability compliance checks are often conducted at the project's end to declare the impacts, typically using life cycle assessments following ISO 14040. However, the usage and end-of-life phases are often neglected. These data are rarely shared with development and design teams, likely due to communication and time constraints (pT.4).

When explicitly asked, all participants stated that the design process for ecosystems of technological products remained largely unaltered based on whether the solution included AI or not, even though most IoT systems incorporate some AI components.

5.4. The current role of designers in ensuring sustainability in AI-infused objects

From all pTs perspective, designers are often perceived as implementers enhancing project aesthetics without substantial decision-making authority. PT6 emphasizes the central role of regulations, whether internal or external, as potent agents of change, favouring a “top-down approach”. In contrast, designers (pDs), especially those in corporate settings, hold a more skeptical view. For instance, pD.8 pointed out “Regulations are often easily circumvented, which prompts us to take autonomous control of the situation". Professional in IOT (pI.4) highlighted that in corporate contexts, junior designers, driven by sustainability consciousness, informally educate themselves through online articles and then share the acquired data with the team, integrating it into the design process to create more sustainable solutions. Often, this information is condensed into personalized tools that can be adapted for other company projects, to avoid lose time in future development. Their focus is often directed towards material reduction within the IoT department or on creating minimalist interfaces” but this is not comprehensive. Academic designers (pD1,4,7,9), stress the need to integrate the impact of ITC products, both within corporate settings and education, “despite the established role of designers in selecting less impactful physical materials for products we need to think to the digital as well” (pD.8). PDs highlight that some tools from design have the potential to analyse the impact of digital products, such as system mapping, can provide valuable insights into user engagement with AI-infused objects. This approach could highlight potential inefficiencies and unnecessary interactions contributing to energy consumption, underscoring the importance of optimizing user experiences. pD3 makes an example, if the use of a voice assistant remains limited to playing music, users might abandon it. Therefore, when users do not engage with the entire ecosystem, a single point of contact might lose significance, contributing to data entropy and energy consumption. Lastly, pTs perspective advocate for impact quantification and transparency in every company producing AI-infused objects, with “data made available to designers for integrating acquired knowledge into future projects” (pT.5).

5.5. Designers' requirements to advance the sustainability dimension of these objects

During interviews, the author employed a lifecycle map of an AI-infused object (appendix C), using color-coded sections to emphasize both tangible and nontangible impacts of these objects. All participants found this narrative approach comprehensible and meaningful, as stated by participant pD.3: "an excellent means to convey the technology's impact to designers and raise their awareness on the impacts generated by the artifacts they design". Next, the author introduced a table outlining AI-infused object components (physical, digital, and usage) based on Arquilla and Paracolli (2023). The proposed division identifies possible impacts associated with each component of an AI-infused object ecosystem serves as a good starting point to guide designers in sustainability-oriented design processes. A critical aspect of the presented materials concerns the role of designers. Participant pI.3 mentioned that designers cannot bear the comprehensive sustainable dimension of AI-infused objects, "they can't fully control what happens in the supply chain or make decisions about which producers to engage with". This falls outside their scope, particularly in companies. Focusing on the impact during usage becomes more significant and impactful from their standpoint to make more effective sustainable decision within the time allocated. On the other hand, the necessity arises for a "method to communicate with developers" (pI.7) to generate solutions that prioritize not only efficiency but also user context and needs during technological development. A matrix could act as a meeting point in the different phase of the project, where the project's system map is condensed, touchpoints define usage and context specifics, and technical requirements are outlined. This aids in pinpointing the least impactful solution while safeguarding the ecosystem's user experience. During the interviews, participant pI.6 mentioned several examples of AI-infused object ecosystems to describe various modes of connection and identified the more energy-intensive ones. This commentary combines quantitative and qualitative data, like describing the interaction within an intelligent objects ecosystem and simplifying its energy consumption into numbers.

Participant pD.5 emphasized that making environmental assessment in existing sustainability tools requires precise data collection. Designers engaged in concept development lack this specific data as they deal with product concepts, not finalized products. Existing tools are time-consuming due to the level of detail they require. Participant pI.4 highlighted the need for something that offers a quick overview of the impacts produced so they can intuitively manage those impacts and make informed trade-offs, utilizing visual examples for each component and assigning a number to its potential impacts. Even from a pTs perspective, the importance of an assessment that combines quantitative and qualitative aspects could be a valuable approach to establish comprehensible benchmarks, even for those less familiar with numerical analysis. This would simplify assessment and identification of potential impacts, along with strategies for addressing them, including compliance with corporate regulations (pT.3). Undoubtedly, raising awareness among designers and anyone involved in designing AI-infused ecosystems is crucial, hence the perspective of education remains central.

6. CONCLUSIONS

The existing body of literature on the environmental impact of AI-infused objects has extensively explored the concept of Life Cycle Assessment (LCA). However, one aspect often overlooked is the profound influence of Artificial Intelligence (AI) on this assessment.

Specifically, dedicated studies on AI-related LCA tend to disregard the physical dimensions of AI-infused objects and the subsequent shifts in user behaviour. Despite AI's potential advantages in enhancing sustainability, it also poses challenges due to its energy-intensive training requirements, substantial data demands, and broad socio-environmental implications.

In navigating these complexities, designers undoubtedly play a pivotal role. It is crucial for them to be aware of the environmental impacts of this technology and discern when and how to integrate AI into objects. However, we must acknowledge that we operate within a complex socio-political system, and in corporate settings, designers are not the sole decision-makers. Recognizing the collaborative nature of decision-making in project development emphasizes that responsibility extends beyond designers to various stakeholders. While designers retain significant influence, it is crucial to extend this recognition to all professionals involved in the development process. In this sense, the insights gained from the 21 interviews further underscore the necessity for effective collaboration and communication between designers, developers, and other stakeholders. In this context, specialized tools and figures can serve as invaluable mediators, ensuring a constant focus on sustainability in design decisions. This research marks a step in systematizing the relationship between AI-infused objects and sustainability, particularly from a design perspective. It identifies practical implications for a nascent field of inquiry where environmental impacts are viewed as creative challenges to surmount, centralizing user needs, and striving for an optimal balance between environmental impact, technological advancement, and human requirements. It is through collaborative efforts that we can drive positive change, recognizing the collective responsibility we all bear in the pursuit of sustainable technological innovation.

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APPENDIX

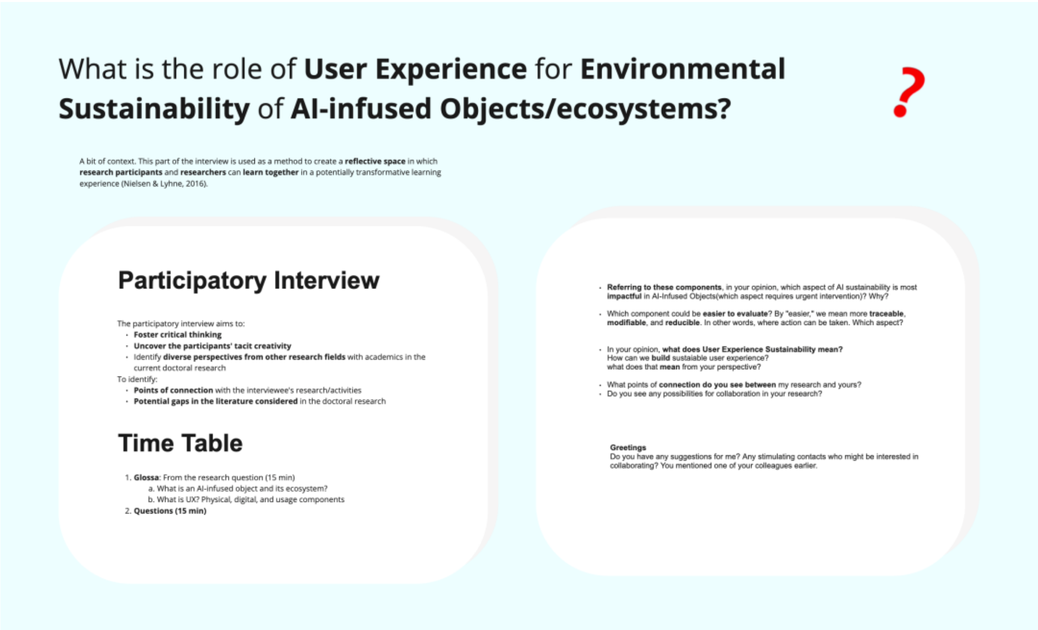

Figure 1. Miro Board - Interview onboarding

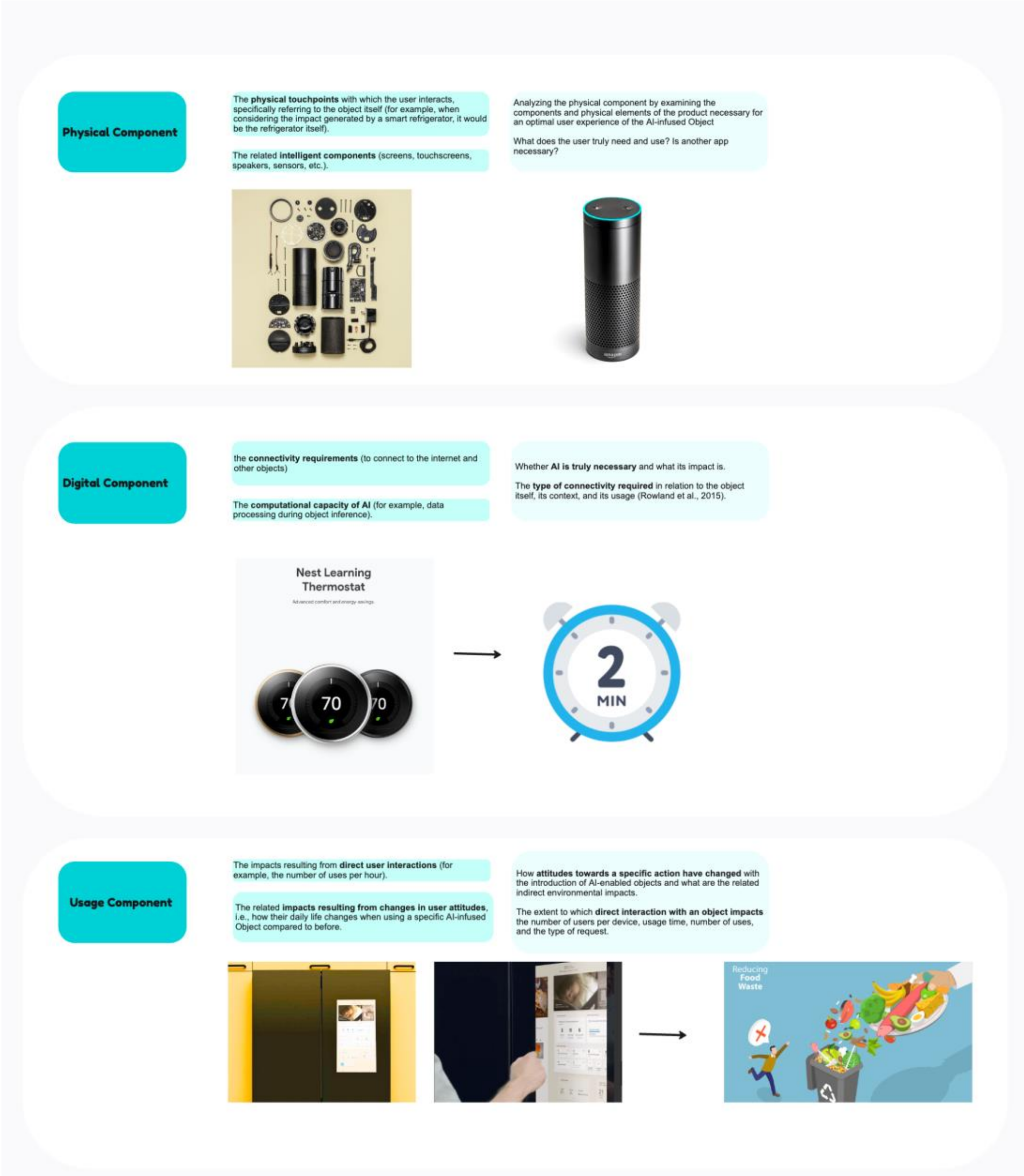

Figure 2. Miro Board - components division

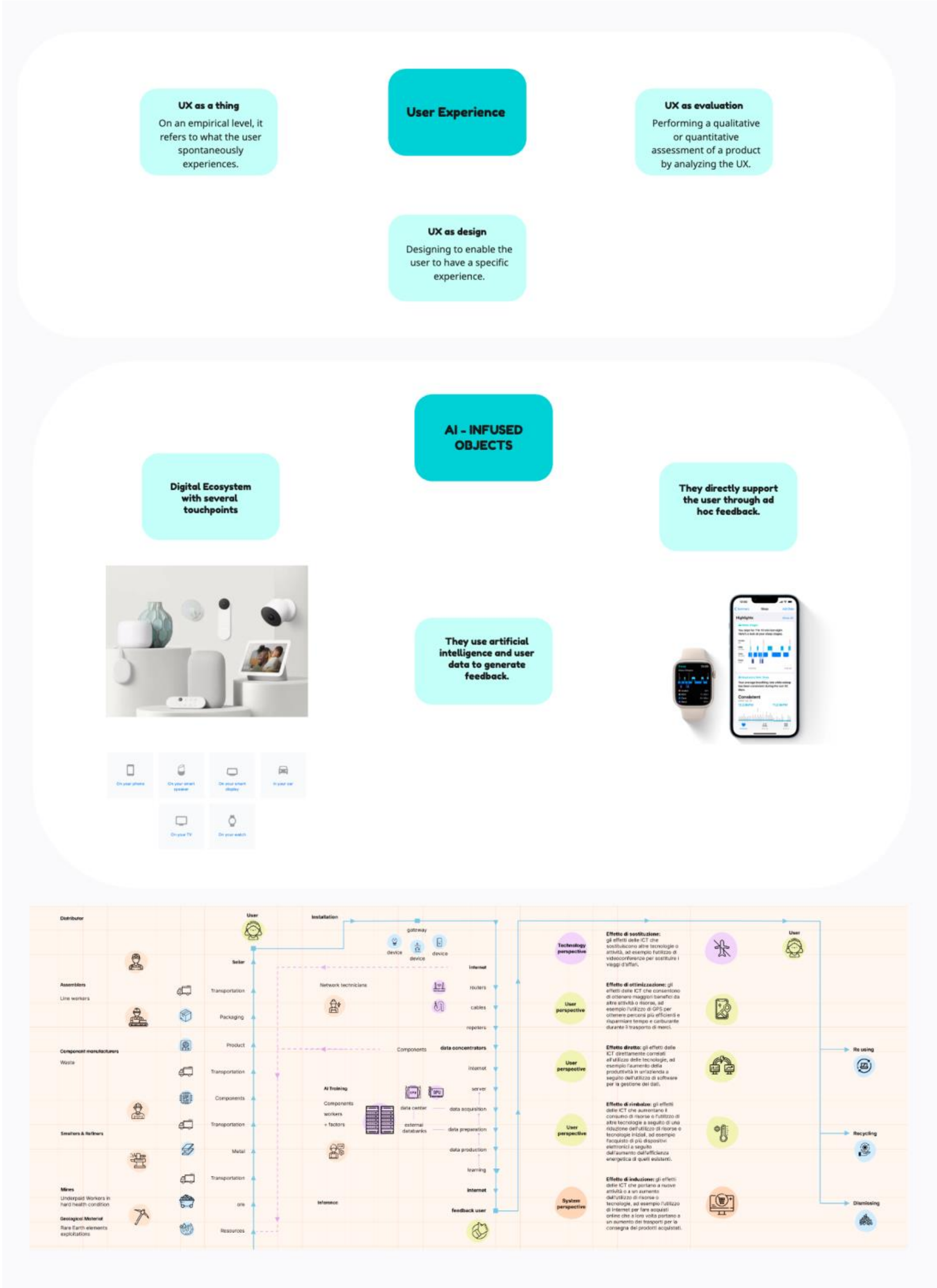

Figure 3. Miro Board - life cycle map of AI- infused objects and definitions

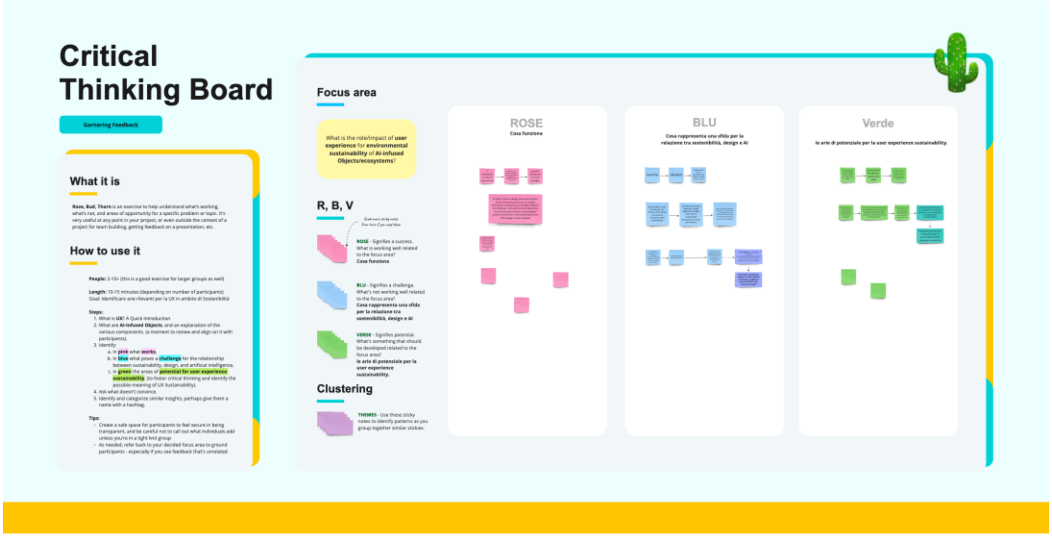

Figure 4.: Miro Board - space for Exchange idea for participants

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