

Humanity-Centered Design in Sustainable Product Design: Literature Review

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ABSTRACT

Product design has emerged as a crucial element in developing innovative solutions that prioritize not only functionality and aesthetics but also sustainability. The Human-Centered Design (HCD) approach has long been employed to ensure that user needs remain the primary focus throughout the design process. However, global challenges such as climate change, social inequality, and the long-term impacts of products necessitate a more comprehensive approach. Consequently, the concept of Humanity-Centered Design has been developed as an extension of HCD, emphasizing the importance of considering the entire ecosystem, other living beings, and long-term consequences in the product design process. This research utilizes a narrative literature review method to examine the Humanity-Centered Design (HuCD) approach within the context of sustainable product design. The review findings indicate that Humanity-Centered Design introduces five key principles, which include a focus on fundamental issues, a holistic ecosystem perspective, long-term outlook, continuous iteration, and community participation. This approach has been shown to enhance the relevance, acceptance, and sustainability of solutions across various sectors, including health technology, manufacturing, and digital domains.

Keyword: Human-Centered Design, Humanity-Centered Design, Sustainability, Product Design

ABSTRAK

Desain produk kini menjadi aspek krusial dalam menciptakan solusi inovatif yang tidak hanya memperhatikan fungsi dan estetika, tetapi juga keberlanjutan. Pendekatan Human-Centered Design (HCD) telah lama diterapkan untuk memastikan bahwa kebutuhan pengguna menjadi prioritas utama dalam proses desain. Namun, tantangan global seperti perubahan iklim, ketidakadilan sosial, dan dampak jangka panjang dari produk memerlukan pendekatan yang lebih menyeluruh. Oleh karena itu, konsep Humanity-Centered Design dikembangkan sebagai perluasan dari HCD dengan menekankan pentingnya mempertimbangkan seluruh ekosistem, makhluk hidup lainnya, dan konsekuensi jangka panjang dalam proses desain produk. Penelitian ini menggunakan metode tinjauan literatur naratif untuk mengeksplorasi metode Humanity-Centered Design (HuCD) dalam konteks desain produk berkelanjutan. Hasil tinjauan menunjukkan bahwa HuCD memperkenalkan lima prinsip utama yang mencakup fokus pada isu mendasar, ekosistem secara keseluruhan, perspektif jangka panjang, iterasi berkelanjutan, dan partisipasi komunitas. Pendekatan ini terbukti meningkatkan relevansi, penerimaan, dan keberlanjutan solusi di berbagai sektor seperti teknologi kesehatan, manufaktur, dan digital.

Keyword: Human-Centered Design, Humanity-Centered Design, Keberlanjutan, Perancangan Produk



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1. Introduction

Design has increasingly become a vital asset for individuals today. It acts as a robust tool for addressing challenges and fostering creative ideas for innovative and disruptive products. As the significance of design methodologies and tools grows, there has been a concerted marketing push for specific tools and

methodologies that are now viewed as the most 'innovative' processes. It is crucial to comprehend the different types of methodologies and tools, along with their respective pros and cons. The design process consists of several stages that must be navigated to develop innovative products, services, or experiences. Some methods focus on specific stages, while others cover a wider array of elements. Certain approaches are qualitative or quantitative, some prioritize research, and others promote creative thinking [1], [2].

To successfully influence consumer purchasing decisions, the development and enhancement of products must meet consumer needs. Furthermore, the design should be visually appealing, improve functionality, ensure ease of use, and reduce operational costs, while also achieving simplicity and efficiency in production and distribution. As noted by Ulrich in 2016, the process of product design and development includes several stages, including planning, concept development, system-level design, detailed design, and testing and refinement [3], [4].

The design process in the scientific field is continually advancing, with new methodologies emerging to adapt to contemporary conditions, aimed at producing high-quality products. The urgency for sustainable product development is escalating. Sustainable development has become a key focus for both current and future generations, considering economic growth, social implications, and environmental sustainability. Over the last forty years, the emphasis on sustainability has increased in alignment with global agendas and environmental policies. This shift has heightened consumer awareness regarding sustainability issues and influenced purchasing behaviours, thereby exerting more pressure on companies and designers to incorporate sustainability into New Product Development (NPD). Consequently, it is crucial for product design to embrace sustainability within NPD to ensure optimal functionality while minimizing the sustainability impact of the product [5], [6].

In the realm of product design literature, numerous terms associated with sustainability are identified, including clean production, eco-friendly design, and green design. The literature also presents a variety of viewpoints concerning the implementation of sustainable practices. According to Venkata Rao, it is essential to adhere to all environmental standards and requirements from the design phase through to the conclusion of the product's life cycle. Design for Sustainability introduces several methodologies that facilitate ongoing enhancement by considering social, economic, and environmental aspects within a product life cycle framework. Conversely, Design for Environment focuses on minimizing the overall environmental impact of a product throughout its entire life cycle [6], [7], [8].

The Human-Centered Design (HCD) approach, which is extensively examined in relation to product design, design thinking, and sustainable design, emphasizes the importance of individuals' needs and experiences in various design contexts, including products, services, and systems. This concept, first introduced in the late 1980s, has gained prominence over the past four decades. While it has numerous benefits and remains a leading methodology, it is now essential to broaden this perspective. Historically, design served primarily as an industrial mechanism aimed at producing mass-market items that were visually appealing, functional, and economically viable. The HCD framework encourages a transition from a narrow focus on production efficiency to a more profound comprehension of human users' requirements [3], [4], [9].

HCD is a methodology that prioritizes the users, ensuring that the entire design process is tailored to address the needs, aspirations, and constraints of the end users. The primary aim is to develop solutions that are pertinent, user-friendly, and efficient. The fundamental tenets of HCD encompass empathy, where designers seek to grasp the experiences and viewpoints of users through direct engagement; user involvement, which highlights the necessity of user participation throughout all phases of the design process; iteration, which entails revisiting the design cycle to enhance the product; and contextual understanding, where solutions are crafted with an awareness of the users' surroundings and cultural backgrounds. While these principles are essential, challenges such as sustainability, inequality, and bias frequently go unaddressed. Moreover, the emphasis often lies on immediate problem-solving, neglecting the long-term consequences. Consequently, these principles represent more of the operational strategies of the past rather than the approach required to tackle the intricate challenges outlined in this book and those anticipated in the future [10], [11].

Consequently, the concept of Humanity-Centered Design (HuCD) has emerged. This approach builds upon the core principles of earlier methodologies while broadening its focus to include all living entities, ecosystems, and the long-term consequences of design. The transition from HCD to HuCD is intended to expand the range

of issues considered, addressing more intricate and comprehensive challenges. By looking beyond the immediate users, HuCD actively aims to incorporate innovation into human activities and systems, taking into account individuals who are not the primary users in the design process, including those who interact indirectly with the innovations, such as communities or the environment [1], [2], [12].

HuCD adopts a systemic perspective that prioritizes human experience and creativity in navigating change, playing a crucial role in tackling the intricate challenges of contemporary care. This discipline concentrates on recognizing human needs, which facilitates the creation of products or services tailored to fulfil those needs. The resulting designs must be intuitive and functional, effectively achieving the intended objectives while offering a meaningful and enjoyable experience for users. A defining characteristic of HCD is its comprehensive and systemic approach to human requirements, ensuring that the solutions developed align with the complexities of socio-technical systems that involve users. It is essential to recognize that 'design' encompasses a wide range of meanings, including both the design process and its outcomes. Moreover, design is increasingly perceived not just as a method for producing tangible products, but as a process that leads to various interventions aimed at transforming current situations into preferred ones [13], [14].

At present, the fields of product design and development encounter several challenges that require designers to have a comprehensive understanding of essential parameters prior to initiating the design process. These parameters include, but are not limited to, customer needs, specific design specifications, and a range of other influential factors. Furthermore, the importance of sustainability cannot be overstated; it is crucial to incorporate sustainable practices into the design process. Additionally, managing and minimizing the product development timeline is a key consideration that designers must address [15], [16]. This article aims to delve into existing frameworks and human-centered methodologies for conducting contextual analysis, with the goal of enhancing design outcomes and ensuring that products meet both user expectations and sustainability standards.

2. Method

This research employs a narrative literature review to explore HCD and HuCD methods in sustainable product design. A narrative literature review is a method that identifies, analyzes, and summarizes previously published literature with the aim of providing an overview of a topic, issue, or phenomenon based on relevant and credible sources [7].

Academic databases such as Google Scholar are utilized to identify relevant articles, books, and published literature. The selection of literature is based on its relevance to the research question, its contributions, and the methodologies employed in the studies. The reviewed literature is sourced from various types of publications, including scientific journals from platforms like ScienceDirect, Taylor & Francis Online, IEEE, and SpringerLink; conference proceedings; and others.

Literature reviews provide numerous benefits, such as determining if an effect is consistent across different studies, pinpointing future research needed to validate that effect, and uncovering which study characteristics or sample traits impact the phenomenon, among other advantages [14].

Table 1. Keywords Literature Identification

Topics		Examples of search terms
Product Design	Sustainability	
Product design, design thinking, product design Development, human-centered design, humanity-centered design, new product development	Environmental sustainability, sustainable development, sustainability design	Product design' AND environmental sustainability, 'Product design' AND sustainable development, Human-centered design AND sustainability design, OR environment sustainability

3. Result and Discussion

HCD is an approach that prioritizes the user, where the entire process is crafted with careful consideration of the needs, desires, and limitations of the end user. Its primary objective is to develop solutions that are

relevant, user-friendly, and effective. The core principles of HCD include empathy, which involves designers gaining insight into the experiences and perspectives of users through direct interaction; user involvement, highlighting the significance of engaging users at every stage of the design process; iteration, which entails repeating the design cycle to refine the product; and understanding context, where solutions are designed with an awareness of the user's environment and culture [17], [18]. HCD is based on four main principles.

1. Addressing fundamental issues rather than merely tackling surface-level problems, which often only represent symptoms of deeper underlying causes.
2. Placing primary emphasis on user needs and experiences.
3. Applying a systemic perspective by recognizing that numerous challenges arise from the interdependencies among various elements.
4. Conducting ongoing testing and refinement of the design to ensure that the solution is fully aligned with the needs and expectations of the users.

Although these principles are crucial, they frequently overlook issues such as sustainability, inequality, and bias. Furthermore, the emphasis tends to be on short-term problem-solving, without regard for long-term consequences. Consequently, these principles reflect past methodologies rather than the approaches necessary to address the complex challenges discussed in this book and those anticipated in the future. Therefore, the concept of HuCD has been developed [19], [20].

HuCD retains the fundamental principles of its predecessor while broadening its scope to consider all living beings, ecosystems, and long-term impacts. The transition from human-centered design to humanity-centered design necessitates the introduction of an additional principle (the fifth principle) and adjustments to the second, third, and fourth principles. This change aims to expand the range of issues addressed, thereby encompassing more complex and holistic concerns [9], [21]. The development of the principles of HCD to HuCD can be outlined as follows.

1. Concentrate on addressing fundamental issues rather than merely focusing on surface-level problems, which are often symptoms rather than the root causes.
2. Consider the entire ecosystem, which includes humans, all living beings, and the physical environment.
3. Adopt a long-term perspective and a systemic approach, recognizing that many challenges arise from the interconnections among various elements, and that the most detrimental impacts on society and ecosystems often only become apparent after years or even decades.
4. Implement continuous testing and refinement of the design to ensure it effectively meets the needs of both humans and the ecosystem it targets.
5. Engage the community in the design process and, whenever possible, support designs that originate from the community. The role of professional designers is to act as facilitators, mentors, and resources, assisting community members in achieving their objectives.

HCD has been the dominant methodology in design for decades, particularly in industry, healthcare, and technology. Its strength lies in creating usable, relevant, and user-friendly solutions quickly. However, because it primarily focuses on the immediate user, it sometimes fails to account for long-term sustainability or wider social impacts. While HuCD expands this view by including the ecosystem, community, and future generations. It pushes design thinking toward systemic change rather than just usability. However, because it is relatively new and more complex, HuCD is less frequently adopted compared to HCD. The differentiate between each methods can be seen in Table 2.

HCD is best used when the design challenge focuses on specific user needs, usability, and short-term functionality. It is particularly effective in contexts where efficiency, practicality, and user satisfaction are the primary goals, such as developing mobile applications, medical devices, digital platforms, or consumer products. Because HCD emphasizes empathy, iteration, and user involvement, it helps ensure that the resulting

solution is intuitive and directly aligned with end-users' experiences. This makes HCD the more frequently used method, especially in industries that prioritize speed to market and customer satisfaction.

Table 2. Comparison Between HCD and HuCD

Aspect	Human-Centered Design (HCD)	Humanity-Centered Design (HuCD)
Focus	End users' needs, usability, and immediate problem-solving.	Entire ecosystem: humans, communities, other living beings, and environment.
Principles	Empathy, user involvement, iteration, contextual understanding.	Fundamental issues, holistic ecosystem perspective, long-term outlook, continuous iteration, community participation.
Scope	Narrower – centered on individuals or target groups.	Broader – considers society, ecology, and sustainability.
Time Orientation	Short- to medium-term (solutions for current user needs).	Long-term (anticipates consequences years or decades ahead).
Applications	Widely used in product/service usability, healthcare tools, digital UX/UI, industrial design.	Emerging in sustainable innovation, social change projects, ecological systems, and policy-driven design.
Designer's Role	Problem-solver who designs <i>for</i> users.	Facilitator/mentor who co-creates <i>with</i> communities.
Limitations	- Overlooks sustainability and long-term impacts. - May reinforce bias or inequality. - Focuses narrowly on user needs, ignoring wider systems. - Solutions risk being short-sighted.	- Complex and resource-intensive. - Hard to balance diverse human + ecological interests. - Community participation can face conflicts or low engagement. - Measuring success (social/ environmental impact) is difficult.

On the other hand, HuCD is most suitable for projects that require a broader, systemic, and long-term perspective. It is especially relevant when design problems intersect with sustainability, social justice, community well-being, and environmental concerns. HuCD is valuable in domains such as urban planning, renewable energy, public health, and sustainable product development, where the consequences of design decisions extend beyond immediate users and may impact future generations. Unlike HCD, HuCD emphasizes the ecosystem, community participation, and long-term outcomes, making it ideal for tackling complex global challenges. In essence, HCD should be used when the priority is usability and immediate problem-solving for specific users, while HuCD should be chosen when the goal is systemic change that balances human, societal, and environmental needs in the long run.

HuCD and HCD both consists of several phases: (1) inspiration, which involves research and a deep understanding of user issues through interviews; (2) ideation, where ideas are generated based on research findings through brainstorming sessions that include users; and (3) implementation, which encompasses prototyping, user testing, and refining the product based on feedback. These steps are iterative, with the design process repeated continuously until it optimally meets user needs. [5], [11], [22]. HuCD process steps can be seen in Fig 1.

1. Inspiration. The inspiration phase represents the initial stage of the HuCD process. This phase primarily focuses on understanding the problem, identifying needs, and fostering empathy for the users. It involves gathering inspiration and researching all aspects of the user segment through observation, interviews, comprehending the current market, identifying opportunities, and essentially gaining insights into users based on their needs. Building empathy for your users is the most crucial aspect of this phase, as it entails truly understanding them and recognizing why they require a product, service, or experience to enhance their quality of life. By acquiring this inspiration from various sources, senses, behaviors, and learning based on the appropriate user segment, more effective solutions can be developed in the subsequent stage using the collected information. [11], [23].

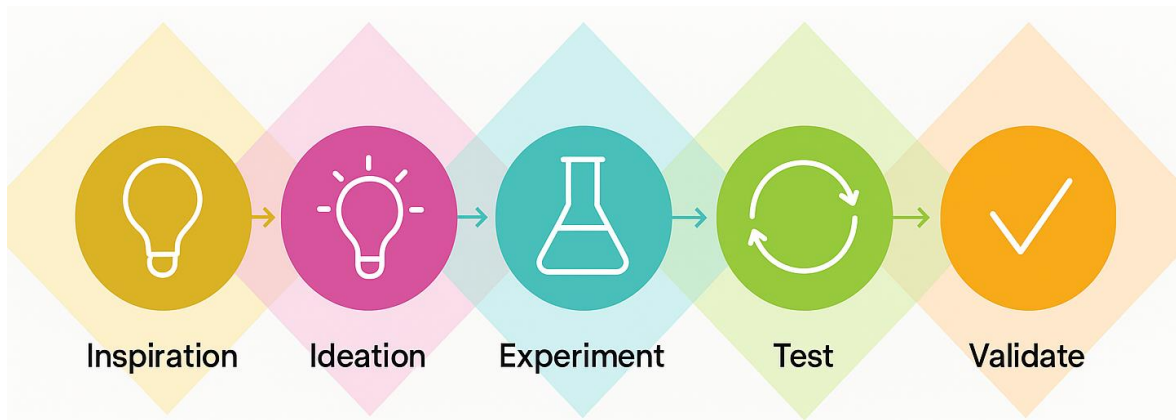


Figure 1. Humanity-Centered Design Workflow

2. **Ideation.** The ideation phase represents the second stage in the HuCD process. It utilizes the information gathered during the inspiration phase to generate new solutions. During this stage, user needs and problem questions must be translated into one or more concepts through brainstorming, creative idea generation, customer journey mapping, and storyboard creation. Concepts should be selected through rapid and high-level testing to quickly validate market segments. This phase is crucial as it marks the beginning of product, service, or experience creation. The key to developing disruptive concepts lies in generating a multitude of ideas, all grounded in user needs and desires, as part of a human-centered approach. Engaging in more creative thinking and dedicating additional time to this stage will yield greater benefits in the development of successful or disruptive products. [5], [19], [20].

3. **Experiment.** The experimental phase represents the third stage in the HuCD process. This phase is entirely focused on experimenting with the concepts generated during the ideation stage to create a functional prototype. Building a prototype is a crucial aspect of the design process; it must effectively translate all user needs and desires and be self-explanatory. Prototypes should be quick to produce, cost-effective, and of low fidelity, allowing for rapid changes and low-cost improvements. This stage should involve very quick and simple testing with users, demonstrating the primary functions of the prototype to gather prompt user feedback, which will inform the decision to either proceed to the next stage or iterate and pivot [4], [12], [18].

4. **Test.** The testing phase represents the fourth stage in the HuCD process. This phase involves the implementation of the final prototype into a functional product and testing it with user segments. It incorporates all ideas, details, information, and modifications gathered from the previous three stages to develop a product, service, or physical or digital experience. Testing the final design with users ensures market fit and provides feedback on how users will interact with the design. Collecting and analyzing qualitative and quantitative data from the testing phase is essential to determine whether the minimum viable product should proceed to production or be revised to better align with market needs [1], [16].

5. **Validate.** The validation phase represents the final step in the HuCD process. This phase involves a thorough examination of the previous four stages, ensuring that the product, service, or experience is viable and can be successfully marketed with a positive return on investment. It is responsible for developing the business model, marketing strategy, customer engagement, and understanding costs and other economic factors. The product, service, or experience can be deconstructed into various sellable components or can serve as a foundation for future products, becoming part of a larger ecosystem [2], [4].

HuCD must incorporate sustainability considerations at every stage of the design process. Each type of design process should include a sustainable approach when developing new products, services, or experiences. Traditional design processes involve the creation, use, and disposal of products, leading to significant waste. Therefore, it is crucial to consider sustainability throughout the design process. [5], [8].

Understanding the implications and impacts of sustainability in products, services, or experiences from the outset is essential for businesses and the future of these concepts. During the ideation phase, it is crucial to comprehend the position, reactions, and needs of users regarding sustainability; how users perceive the product, how they utilize it, and how they dispose of it. Empathy is necessary to grasp users' lifestyles and their ideas about materials and recycling [5].

HuCD is an approach to design that prioritizes the needs, desires, and limitations of users at every stage of the design process. This approach has been utilized across various fields, including food technology, healthcare, digital retail, and built environments. The following studies illustrate the successes and challenges of implementing HCD in different contexts.

Table 3. Literature Review

No	Author (Year)	Methods	Major Findings
1	Zhang et al. (2024)	Systematic Literature Review, Human-Centered Design	Six main themes of HCD perception, behavior, indoor air quality, communication, user satisfaction, and energy.
2	Nguyen et al. (2022)	Systematic Literature Review, Human-Centered Design	Establishing a comprehensive thematic framework for Human-Centered Design within the context of Industry 4.0, which includes an exploration of the various challenges and opportunities associated with its integration.
3	Giacobone & Mincolelli (2020)	Quality Function Deployment, Human-Centered Design	The combination of Human-Centered Design (HCD) and Quality Function Deployment (QFD) is utilized to effectively link the requirements and preferences of users with the specific technical design parameters of a product.
4	Bowman et al. (2017)	Systematic Literature Review, Human-Centered Design	A compact medical device designed for portability that leverages biomarkers for health monitoring, integrating human-centered design principles from the very beginning of its development process.
5	Melles et al. (2020)	Systematic Literature Review, Human-Centered Design	Three key characteristics of Human-Centered Design (HCD) are user understanding, which emphasizes the importance of deeply comprehending the needs, preferences, and behaviors of the end users. Another essential aspect of HCD is engagement, which focuses on actively involving users throughout the design process. Lastly, a systemic approach is a fundamental characteristic of Human-Centered Design. This means considering the broader context in which the design will be used, including the social, cultural, and environmental factors that may influence user interactions.
6	Heller et al. (2021)	Systematic Literature Review, Human-Centered Design	Assessing the effectiveness of Human-Centered Design (HCD) in global health interventions presents several challenges, including cultural differences, varying health literacy levels, and the complexity of health systems.
7	Setiadi & Setiaji (2023)	Systematic Literature Review, Human-Centered Design	The adoption of a three-stage Human-Centered Design (HCD) methodology in creating a second-hand e-commerce platform involves a systematic process that prioritizes the needs and experiences of users throughout the design journey.
8	AHFE (2021)	Systematic Literature Review, Human-Centered Design	Human-Centered Design (HCD) plays a crucial role in improving both efficiency and safety in single-pilot systems. This approach minimizes cognitive overload, allowing the pilot to make quicker and more accurate decisions, which enhances overall operational efficiency.
9	Kigozi et al. (2024)	Human-Centered Design	The redesign of the equipment (pulper and pasteurizer) to meet user requirements enhances technology adoption and the potential for reducing postharvest losses.
10	Arrivillaga et al. (2024)	Human-Centered Design	The combination of Human-Centered Design (HCD) and Artificial Intelligence (AI) produces devices that are ergonomic, comfortable, and effective for use in resource-constrained environments.
11	Hua et al. (2025)	Human-Centered Design	HCD facilitates the customization of digital promotion strategies to enhance the consumption of fruits and vegetables among individuals with diabetes and obesity.

No	Author (Year)	Methods	Major Findings
12	Ambrogio et al. (2025)	House of Quality, Human-Centered Design	Aligning patient needs with technical specifications in a systematic manner to produce personalized prosthetics.
13	Khan & Lucas (2025)	Systematic Literature Review, Human-Centered Design	Identification of the integration of HCD principles (biophilic, acoustic, lighting, IoT) to enhance the comfort and well-being of occupants.

The AHFE report in 2021 emphasizes the implementation of HCD in the development of Single Pilot Operations (SPO) within the commercial aviation industry. Utilizing a systematic literature review and scientometric analysis, this study categorizes advancements in HCD into three primary areas: conceptual design, function allocation, and system evaluation. The application of HCD in SPO aims to enhance system efficiency while ensuring the safety and comfort of pilots as the primary users. From a sustainability perspective, this approach reduces reliance on additional crew, which can lower carbon emissions from logistical operations and expedite the transition to a more resource-efficient automated aviation system [10].

Nguyen et al. conducted a systematic review of case studies on the application of HCD within the context of Industry 4.0, particularly in smart manufacturing environments. This study identified a lack of cohesive structure in the integration of HCD approaches and proposed a new framework to bridge the gap between technology and human roles. The journal's significant contribution lies in mapping themes of human-centered design, such as operator engagement, empathy in tool design, and human-machine interaction. In terms of sustainability, HCD in Industry 4.0 fosters user-friendly and adaptive systems that promote more efficient, ergonomic, and waste-minimizing production, while enabling workers to swiftly adapt to variations in products and processes [12].

Zhang et al. present a comprehensive review of HCD practices in building engineering and the built environment, utilizing both bibliometric and qualitative analyses of literature from 2010 to 2023. Six primary domains of HCD identified include spatial perception, indoor environmental behavior, communication, user comfort, indoor air quality (IAQ), and energy sustainability. HCD is employed to tailor building designs to meet the psychological and physiological needs of occupants. The connection to sustainability is notably strong, as user-centered design leads to energy-efficient buildings that enhance occupant health and reduce carbon footprints through intelligent systems responsive to user behavior [13].

Setiadi et al. implemented a practical application of HCD in the user interface (UI/UX) design for the e-commerce platform 'Thriftdoor' specializing in secondhand goods. The research followed three primary stages of HCD: inspiration, ideation, and implementation, utilizing methods such as observation, interviews, and prototyping. The emphasis was placed on transaction comfort, security, and user trust when purchasing secondhand items. From a sustainability perspective, this project promotes a circular economy by extending the product lifecycle through the sale of used goods, reducing electronic and textile waste, and encouraging more responsible consumption among students and the general public [16].

Giacobone et al. integrate HCD with Quality Function Deployment (QFD) in the context of sports vehicle interface design. This qualitative study highlights the significance of understanding user needs from the early stages to translate them into technical design parameters. In this context, HCD serves as a bridge between engineering and user experience. Regarding sustainability, vehicle designs that prioritize human comfort and adaptability can lead to products that are safer, more energy-efficient, and reduce the cognitive load on drivers, particularly in the increasingly advanced mobility of the future [2].

Bowman et al. describe the development of the OccuCheck medical diagnostic tool using a HCD approach that involves healthcare professionals and patients from the outset of the design process. The objective is to create a portable, intuitive tool that can be utilized in various patient conditions. HCD is applied in design decision-making concerning ergonomics, patient comfort, and usage protocols. Its connection to sustainability lies in the efficiency of the diagnostic process, the reduction of the need for large equipment (such as Slit Lamps), and the enhancement of access in remote areas, which decreases travel costs and healthcare system resource expenditure [18].

Melles et al. elaborated on three primary characteristics of HCD: a profound understanding of human needs, early stakeholder engagement, and a systemic approach across multiple levels (micro-meso-macro). This study is theoretical in nature yet highly pertinent to the transformation of healthcare systems towards a more humanistic and adaptive framework. HCD is positioned as a tool for systemic change in healthcare service innovation. In relation to sustainability, the principles of HCD contribute to the creation of efficient, inclusive, and sustainable healthcare systems, as empathetic design decisions and user participation help to prevent resource waste and systemic errors [11].

Heller et al. focus on the challenges and strategies involved in measuring the impact of HCD in the realm of global health. The study employs case studies to assess the role of metrics during the design, iteration, and adaptation phases of projects. The research underscores the significance of balancing flexible design methods with rigid health measurement approaches. Its relevance to sustainability lies in the drive to develop community-based health systems that are responsive, measurable, and contextual, ultimately leading to more effective, efficient interventions that support long-term resilience [17].

Kigozi et al. adopted a HCD approach to enhance the adoption of food processing technologies (pulper and pasteurizer) among micro, small, and medium enterprises (MSMEs) in Uganda. The previous design utilized a conventional approach that did not involve end-users, resulting in low adoption rates of the equipment. By implementing HCD, design iterations were made based on user feedback, training, and the development of user manuals. This study demonstrates that direct user involvement in the design process can improve the alignment of technology with user needs while also strengthening the sustainability of small agro-industrial businesses [22].

Arrivillaga et al. developed CITOBOT, a portable device for cervical cancer screening, by integrating HCD, smart prototyping, and artificial intelligence (AI). Through iterative design and repeated testing, the needs of users, both patients and healthcare professionals, were identified and incorporated into the device's design. The integration of AI aids in the classification of cervical images, while the ergonomic design focuses on patient comfort and ease of use. This study highlights the significance of multidisciplinary collaboration and continuous feedback in creating effective and sustainable medical innovations within resource-limited settings [23].

Ambrogio et al. developed a multidisciplinary framework for prosthetic design based on HCD, incorporating technologies such as digital twins, machine learning, and network engineering. This framework utilizes the House of Quality method to align patient needs with technical specifications. The study emphasizes the significance of a systemic and data-driven approach in personalizing health devices [9].

Based on the reviewed literature, HCD has proven to be an effective and flexible approach to creating solutions that are more relevant, acceptable, and sustainable across various contexts. The success of HCD lies in its ability to accommodate user needs directly through collaborative and empathy-based design iterations. Moving forward, the adoption of HCD needs to be supported by policies, participatory design infrastructure, and cross-sector engagement to maximize its impact.

4. Conclusion

Humanity-Centered Design (HuCD) represents an advanced design methodology that builds on Human-Centered Design (HCD) by providing a more comprehensive and inclusive viewpoint. While HCD primarily addresses the needs and comfort of individual users, HuCD extends its focus to encompass the entire ecosystem, communities, and the long-term social, economic, and environmental ramifications of design decisions. This approach is increasingly pertinent given the escalating global urgency surrounding sustainability challenges, climate change, and the necessity for inclusive and sustainable innovation. The literature review in this journal highlights that the consistent application of HuCD leads to beneficial outcomes across various sectors, including health technology, manufacturing, and digital industries. This methodology not only results in products that better meet user needs but also improves technology adoption, enhances resource efficiency, and encourages the development of solutions that consider both human and environmental factors. Key principles of HuCD, such as empathy, iteration, community involvement, and systemic thinking, support the creation of solutions that are technically effective as well as socially and ecologically sustainable. Looking forward, the successful implementation of HuCD depends significantly on the backing of diverse stakeholders, including government, industry, academia, and civil society. It is crucial to establish policies that

encourage participatory design, create infrastructure that supports cross-sector collaboration, and foster a collective understanding that design should not only address immediate problems but also facilitate long-term social and environmental change. Thus, Humanity-Centered Design should be regarded as a fundamental framework for developing responsible and sustainable products, services, and systems.

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