E-ISSN: 2147-6683

Artium

Architecture, Urbanism, Design and Construction

Vol. 12, Issue 1, February 2024

Journal homepage: http://artium.hku.edu.tr

DOI: 10.51664/artium.129881

Designing for Sustainability: The Role of Industrial Design and Designers in Creating a Culture of Sustainability

Research Article
Araştırma Makalesi

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ABSTRACT

This study highlights the urgent need for organizations to adopt sustainable practices in response to the environmental impact of human activities. It focuses on the crucial role of industrial design in fostering a sustainable organizational culture, balancing economic, social, and environmental factors. The research conducts a thorough literature review to assess how industrial design can enhance sustainability and mitigate environmental damage. It explores sustainability frameworks, the evolving responsibilities of designers, and the challenges and opportunities in creating sustainable products. The findings emphasize the importance of sustainable practices in businesses and communities, particularly the unique impact of industrial designers. The study concludes with recommendations for businesses to promote a sustainable culture, underlining the significant role of industrial design in realizing long-term sustainability objectives. sustainable industrial design, design for sustainability, environmental responsibility in design, corporate sustainability strategies

ARTICLE HISTORY
Received 18 / 05 / 2023
Accepted 27 / 11 / 2023

KEYWORDS
Design for sustainability
Sustainable industrial design
Environmental responsibility in design
Corporate sustainability strategies

Sürdürülebilirlik için Tasarım: Sürdürülebilirlik Kültürü Oluşturmakta Endüstriyel Tasarım ve Tasarımcıların Rolü

ÖZ

Bu çalışma, insan faaliyetlerinin çevresel etkilerine karşılık olarak kuruluşların sürdürülebilir uygulamaları benimsemesine duyulan ihtiyacı vurgulamaktadır. Ekonomik, sosyal ve çevresel faktörleri dengeleyen sürdürülebilir bir kurumsal kültürün teşvik edilmesinde endüstriyel tasarımın önemli rolüne odaklanmaktadır. Araştırma, endüstriyel tasarımın sürdürülebilirliği nasıl geliştirebileceğini ve çevresel zararı nasıl azaltabileceğini değerlendirmek için kapsamlı bir literatür taraması yapmaktadır. Sürdürülebilirlik çerçevelerini, tasarımcıların gelişen sorumluluklarını ve sürdürülebilir ürünler yaratmadaki zorlukları ve fırsatları araştırmaktadır. Bulgular, işletmelerde ve toplumlarda sürdürülebilir uygulamaların önemini, özellikle de endüstriyel tasarımcıların etkisini öne çıkarmaktadır. Çalışma, uzun vadeli sürdürülebilirlik hedeflerinin gerçekleştirilmesinde endüstriyel tasarımın önemli rolünün altını çizerek, işletmelerin sürdürülebilir bir kültürü teşvik etmelerine yönelik önerilerle sonuçlanmaktadır.

MAKALE BİLGİSİ
Geliş 18 / 05 / 2023
Kabul 27 / 11 / 2023

ANAHTAR KELİMELER
Sürdürülebilirlik için tasarım
Sürdürülebilir endüstriyel tasarım
Tasarımda çevresel sorumluluk
Kurumsal sürdürülebilirlik stratejileri

INTRODUCTION

The burgeoning interest in embedding sustainability principles across various human endeavors, particularly in product and systems design, responds to increasing concerns about environmental sustainability's long-term viability (Ceschin & Gaziulusoy, 2016; Waage, 2007). The discipline of industrial design, with its core focus on developing and refining products, is identified as pivotal in achieving these sustainability goals (Tischner &

Cited / Atıf: Demirci Berberoğlu, H.M. (2024). Designing for Sustainability: The Role of Industrial Design and Designers in Creating a Culture of Sustainability. *Artium*, 12 (1), 31-43. https://doi.org/10.51664/artium.129881

Charter, 2017). This paper situates itself within the broader context of this discipline, which has undergone a significant evolution in recent decades. Previously characterized by a primary focus on aesthetics and functionality, industrial design has shifted towards integrating sustainability principles into its design methodologies (Meyer & Norman, 2020; Ramirez, 2006). This transition in industrial design aligns with the objectives of this research, which investigates how sustainability can be effectively incorporated into product design to enhance user experiences while mitigating adverse environmental impacts. The paper thereby contributes to the ongoing discourse in industrial design, emphasizing the critical need for sustainable practices and strategies in product development.

Sustainability has gained significant importance across various industries, including industrial design (Ahmad et al., 2018; Ceschin & Gaziulusoy, 2016; Melles et al., 2011). By producing socially and environmentally conscious products, industrial designers have an essential role in promoting sustainable practices. As a result, this essay investigates how industrial design and designers contribute to sustainable design and developing a sustainable culture.

Due to the growing necessity to implement sustainable production and consumption habits, research on the role of industrial design, designers, and researchers in developing a culture of a sustainable future is crucial. Furthermore, employing criteria to evaluate and analyze the effect of sustainable design on sustainability may verify that sustainable design principles effectively encourage the development of a sustainable future. Industrial designers, educators, and industry stakeholders may find the research's findings beneficial in incorporating sustainability principles into their practice and fostering an environmentally friendly future.

The following research questions are arranged in order to determine the critical characteristics that enable industrial designers to contribute to a sustainable future:

- How do companies, industrial designers, and design contribute to creating sustainable products and processes?
- What effects does sustainable design have on social and environmental sustainability?

The study begins by defining sustainability and explaining its significance in industrial design. The following section explains the current research on sustainability in industrial design and emphasizes the significant difficulties designers confront while promoting sustainable practices.

The study is concluded by discussing the sustainable design implications and the potential advantages of promoting a sustainability culture among designers. The study emphasizes that industrial design practices must actively support sustainability to create a sustainable future for everyone. The findings of this study will provide industrial designers, educators, and other industry stakeholders additional information on how to incorporate sustainability concepts into their work and support a sustainable future.

A thorough analysis of the literature on sustainability and industrial design is provided in the next section. The research methodology, reviewed articles, data collection, and analysis procedures are covered in the methodology section. The research results are shared in the results section and then further explained and analyzed in the discussion section. This section also provides suggestions for future research and implementation. In the end, the study concludes by summarizing the research and its contributions to industrial design practice.

OVERVIEW OF SUSTAINABILITY

In recent years, sustainability has gained more attention as people become increasingly aware of the environmental, social, and economic impacts of human activity. It is a complex and diverse topic that requires careful consideration. According to Elkington (1997), sustainability is the capacity of a system, community, or organization to persist throughout the duration through a combination of societal, economic, and environmental variables. This definition emphasizes the importance of balancing the three sustainability structures: social, economic, and environmental.

Implementing sustainable practices and concepts across various industries, including design, is crucial to achieving sustainability. According to McDonough and Braungart (2002), sustainable design aims to produce products, services, and systems that are naturally resilient and meet current and future demands. Cradle-to-cradle design, which aims to produce products that are not only environmentally friendly but also socially and economically sustainable, is the foundation of sustainable design. Additionally, environmentally friendly product design has significantly impacted society and the environment. For example, environmentally friendly product design can reduce greenhouse gas emissions, preserve biodiversity, and advance social justice and inclusivity (Lofthouse & Prendeville, 2018). Nevertheless, there are various barriers to adopting sustainable product design approaches, including knowledge gaps, shortage of funds, and conflicting priorities (Clark et al., 2009).

The Role of Industrial Design in Sustainability

Since designers are responsible for designing products that could lessen the adverse effects on the environment, economy, and society, industrial design is essential for developing a sustainable culture (Keitsch, 2012). The significance of industrial design and designers in fostering a sustainable culture is covered in this heading.

Reduced environmental effect of products is one of industrial design's significant contributions to developing a sustainable culture (Tukker & Jansen, 2006). Industrial designers may accomplish this by creating products that are easy to recycle or reuse, consume fewer resources during manufacture, and are made from sustainable materials. For instance, to lessen the product's

environmental impact, a designer might design one using recyclable or renewable materials such as bamboo (Wang & Yin, 2014).

Industrial design may contribute to developing a sustainable culture by addressing social and economic problems and minimizing the adverse effects of products on the environment. For instance, a designer might design an item that provides employment possibilities for people in underdeveloped nations (Ayeyemi, 2013) or a product that is more usable by those with impairments (Newell & Gregor, 2000). Industrial design could develop a more egalitarian and sustainable society.

Industrial designers should consider a product's entire lifecycle when creating sustainable products. This includes the product's production, consumption, distribution, and disposal. Designers may find ways to lessen the product's environmental impact throughout each phase by contemplating the entire lifetime. To illustrate, a designer might design a product requiring less packaging or using less energy during manufacture, reducing waste (Russell, 2014; Seow, Rahimifard & Woolley, 2013). The end of the product's life and how it will be disposed of should also be considered by designers.

Historical Context of Sustainable Design

Sustainable product design originated from the environmental movement of the 1960s and 1970s, which aimed to increase awareness of the negative impact of industrialization on the environment (Johnson & Greenberg, 2017). At that time, many people were worried about the decline in biodiversity and air and water pollution. They were concerned about how these problems were affecting human health and well-being. In response to these concerns, designers and environmentalists began searching for alternative approaches to creating things that were more sustainable and respectful of the environment (Taylor, 2017).

The concept of environmentally conscious product design gained significant traction in the 1980s and 1990s. "Eco-design" means producing objects with the least possible negative environmental impact (Romli et al., 2015). Several organizations and programs were founded to promote sustainable product design, such as the European Union's Eco-Design Directive and the Design Council's "Design for Sustainability" (HTTP 1, 2023) program.

Early sustainable product designs from the 1980s and 1990s frequently concentrated on minimizing products' adverse environmental impact using resources and energy (Taylor, 2017). For instance, designers started using recycled and renewable materials to create more energy-efficient products (Eriksen et al., 2019; Yang et al., 2014).

The emphasis on social and economic sustainability in sustainable product design continued to develop in the 2000s and 2010s (Taylor, 2017). Fairtrade, ethical production practices, and manufacturing products that benefited their customers and communities economically and socially were all part of this (Cherrier, 2007; Siegford, 2008).

Current State of Sustainable Design

Expanding awareness of the necessity for more sustainable and responsible product design practices may be employed to describe the current state of sustainable product design. Sustainability has become a significant global concern due to critical issues such as climate change, environmental degradation, and socio-economic inequalities.

Organizations have significantly altered their approach to product design in response to these concerns. Since sustainability is both an ethical necessity and a competitive edge, many organizations implement it into their strategic planning. Companies are gradually utilizing sustainable materials, reducing waste, and producing recyclable, long-lasting, and simple products to fix (Bocken et al., 2016; Bulei et al., 2018; Camilleri, 2019).

Using technology to increase a product's sustainability is an emerging trend in sustainable product design. In addition, many companies assess the environmental impact of their products and search for strategies for reducing that impact using data analytics and artificial intelligence. Other companies produce more sustainable items using cutting-edge materials like bioplastics and nanomaterials (Stevens, 2021; Wang et al., 2021).

Despite various promising advancements, significant challenges in using environmentally friendly product design techniques still need to be addressed. A significant obstacle is a consistent definition of sustainable product design. This can cause confusion and uncertainty for both designers and users (Meuer, Koelbel & Hoffmann, 2020). To ensure that designers have the abilities and knowledge to produce truly sustainable products, there is a need for improved education and training.

Balancing sustainability with other design considerations, such as utility and aesthetics, takes time and effort. Sustainable product design necessitates a comprehensive strategy considering each stage of a product's lifecycle, from conception and production to its use and disposal. This may be problematic, particularly when aspects conflict with other design priorities.

In conclusion, a growing awareness of the need for more sustainable and responsible design processes characterizes the current state of sustainable product design. Many businesses now prioritize sustainable design to address climate change, environmental degradation, and social inequality. The lack of a standard definition of sustainability, the need for improved learning and instruction for designers, and the requirement to maintain equilibrium between sustainability and other design concerns remain significant barriers to the broad adoption of sustainable product design practices.

Sustainability Frameworks and Principles

Frameworks and principles for sustainability are collections of concepts and strategies used in decision-making and sustainable development. The selected frameworks and principles offer sustainable development and decision-making guidelines in various contexts,

including industry, politics, and society. By applying these frameworks, designers, and organizations can work towards creating a sustainable and equitable future for all stakeholders. Moreover, they also provide a guide for understanding sustainability's complex and interwoven nature.

The "Triple Bottom Line" framework balances economic, social, and environmental factors in decision-making for organization and development. This acknowledges that sustainable development necessitates a holistic approach to decision-making to fulfill the requirements of individuals, the environment, and profits (Elkington, 2013).

The United Nations Sustainable Development Goals (SDGs); the United Nations created the Sustainable Development Goals in 2015, a set of 17 objectives to address the urgent social, economic, and environmental challenges of our world. The goals address various issues, including sanitation and water quality, biodiversity, gender equality, health, education, and gender inequality (Ferranti, 2019).

The Natural Step Framework is a scientific strategy for sustainability constructed on four tenets: an emphasis on sustainable solutions, the necessity of operating within the ecological boundaries of the planet, the significance of securing economic and social equity, and the requirement for a collaborative, problem-solving strategy for sustainability (Schaltegger, Hansen & Lüdeke-Freund, 2016).

The Cradle-to-Cradle (C2C) Framework: The "cradle-to-cradle" design approach strives to create objects that can be recycled or reused once they have served their purpose. This is founded on ideals of water management, clean energy, and minimizing waste and materials (Bakker et al., 2010).

The Circular Economy is a restricted method of resource utilization, reduced waste, and sparing use of non-renewables are the objectives of the circular economy. It consists of creating resilient, recyclable, and repairable products using resources that may be reused quickly and efficiently (Kopnina, 2018).

Exploring diverse sustainability frameworks and principles – such as the Triple Bottom Line, the United Nations Sustainable Development Goals, the Natural Step Framework, the Cradle-to-Cradle approach, and the Circular Economy – provides a robust foundation for understanding the multi-faceted concept of sustainability. These frameworks, with their focus on balancing economic, social, and environmental factors, set the stage for the subsequent methodological exploration in the paper. Through its systematic literature review, the methodology section seeks to apply these theoretical constructs to the real-world context of industrial design. By examining how designers and the field of industrial design contribute to sustainable cultural development, the research methodically assesses the practical application of these frameworks. Thus, the study not only delves into the theoretical aspects of sustainability but also critically evaluates their practical implementation in industrial design, thereby establishing a comprehensive link between sustainability principles and their application in fostering a sustainable future.

METHODOLOGY

This research paper examines the impact of designers and industrial design on sustainable cultural development. It involves a comprehensive analysis of existing literature on sustainable product design, the role of industrial design, and designers' contributions towards sustainable development. The paper aims to clarify whether the focus is on organizations or designers as experts and industrial design as a discipline contributing to sustainable cultural development. This is achieved through a systematic literature review, gathering and analyzing data to provide insights into the subject matter.

Search Strategy:

The search strategy for this study involved searching relevant electronic databases, including Google Scholar, Scopus, and Web of Science. The search terms included "sustainable product design," "industrial design," "sustainability frameworks," "sustainable development," and "designer's role in sustainability." The results were narrowed down by only considering articles written in English and published between 2010 and 2022. The search results were filtered using the following inclusion and exclusion criteria.

Inclusion Criteria:

- Articles that discuss the role of industrial design and designers in sustainable development.
- Articles that discuss the use of sustainability frameworks and principles in product design.
- Articles that delve into the obstacles and possibilities of creating sustainable product designs.

Data was gathered from the chosen articles that were read in their entirety and were pertinent. The authors, the year of publication, the research questions, the methodology, the key conclusions, and the study's constraints were all included in the data that was extracted.

A content analysis methodology was used to organize and analyze the retrieved material. Identifying recurring themes and patterns in the literature concerning the contribution of industrial design and designers to developing a sustainable culture was part of the content analysis. Categories and subcategories were created for the themes.

The potential bias in the literature and the exclusion of papers written in languages other than English were two of the study's limitations. The quality and scope of the recognized literature constrained the study. By employing a methodical approach to the literature evaluation and outlining the inclusion and exclusion criteria, the study did, however, attempt to offset these limitations.

RESULTS

Using the electronic database search, 52 publications were found, and 31 papers were included in the final evaluation based on the inclusion and exclusion criteria. The chosen papers varied in subject matter from industrial design to the function of designers in sustainable development.

Four major topics about the function of industrial design and designers in fostering a sustainable culture were found in the review:

(1) sustainability frameworks and principles,

(2) designer's role in sustainable product design,

(3) challenges and opportunities for sustainable product design, and

(4) impact of sustainable product design on society and the environment.

Sustainability Frameworks and Principles (Theme 1)

Sustainability is a crucial concern for designers and researchers creating responsible systems and products. To accomplish this goal, designers should comprehend and incorporate sustainability frameworks and principles into their design processes. The present state of research on sustainability frameworks and principles in design, as well as its consequences for design practice, are examined in this literature review. The study discovered many sustainability frameworks and concepts in earlier parts that could serve as a design foundation for sustainable products. The assessment emphasized how crucial it is for designers to use these frameworks to guide their projects.

Ceschin and Gaziulusoy (2016) explore the new approach to sustainable design. Rather than focusing solely on product design, it emphasizes the importance of system innovations and transitions. The writers argue that as designers have realized the importance of addressing sustainability's intricate and linked difficulties, there has been a shift in emphasis from product design to systems design. The authors present three levels—product design, service design, and system design—of a framework for sustainability. They argue that each level builds on the one before it, and the ultimate objective is to design for system improvements and transitions that can fundamentally transform systems and whole businesses.

Ilieva et al. (2022) argue that biomimicry, which entails using nature as inspiration to address design problems, may effectively achieve sustainability. The authors stress the value of comprehending and modeling the efficient, resilient, and sustainable design principles that nature has developed over billions of years. Additionally, they draw attention to how biomimicry may help reduce waste, energy use, and environmental effects.

Keskin et al. (2022) provide a framework for integrating sustainability assessments into the business model innovation process. The authors argue that sustainability should be a significant factor when developing new business models and offering suggestions. On the other hand, Blizzard and Koltz (2012) state that rather than considering the larger systems in which they are embedded, present design techniques are frequently concentrated on fixing specific problems. This may have unforeseen adverse effects and prevent achieving long-term sustainability objectives. Thus, the article provides a four-step framework for designing whole sustainable systems, which entails defining the system and its boundaries, analyzing the system to find critical drivers and feedback loops, developing and assessing design options, and finally, putting the design into practice and monitoring it. The authors illustrate each phase with examples and stress the value of interdisciplinary cooperation and a systems-thinking methodology.

The authors note that traditional models of innovation need to sufficiently address sustainability into consideration as they begin by analyzing the significance of sustainability in business. The authors provide a framework for sustainability evaluations based on four fundamental ideas: holistic thinking, involvement, adaptability, and transparency. These guidelines offer a structure for performing sustainability assessments with fresh business models. Ultimately, the article argues that sustainability assessments should be essential to developing new business models and offers a methodology for creating efficient sustainability evaluations. The authors stress the significance of considering the social, environmental, and economic effects of business models, and they contend that sustainability evaluations may ensure that these effects are maximized and minimized in business model creation.

Designers may employ many sustainability frameworks to influence their design processes. To illustrate, using the Cradle to Cradle (C2C) design framework in the creation of a closed-loop product is the subject of research by de Pauw, Karana, and Kandachar (2013). The authors contend that a potential strategy for attaining sustainable design is the C2C framework, which aims to produce products and systems that are waste-free and regenerative.

The concept of socially responsible design, which goes beyond the conventional triple bottom line (TBL) approach of considering social, environmental, and economic factors, is covered in the article by Melles, de Vere, and Misic (2011). According to them, a responsive design also means considering the requirements and values of various stakeholders, such as the communities and people impacted by the design.

In addition to frameworks, to emphasize the challenges designers confront due to a lack of information, funding, and incentives, Tischner and Charter (2017) underline designers' importance in promoting sustainable design. In order to accomplish sustainable design, the writers claim that cooperation amongst various stakeholders, including designers, manufacturers, legislators, and consumers, is vital.

Table 1. Selected Sustainable Design Approaches and Theories

Author(s)	Framework /Principle	Key Insights
Ceschin & Gaziulusoy (2016)	Systems Design	Shift from product design to systems design, emphasizing system innovations and transitions.
Ilieva et al. (2022)	Biomimicry	Using nature as inspiration for sustainable, efficient, and resilient design.
Keskin et al. (2022)	Sustainability Assessments in Business Models	Integrating sustainability into the development of new business models.
Blizzard & Koltz (2012)	Whole Sustainable Systems Design	A four-step framework for designing sustainable systems, stressing interdisciplinary collaboration.
De Pauw, Karana, & Kandachar (2013)	Cradle to Cradle (C2C)	Focus on creating waste-free and regenerative products and systems.
Melles, de Vere, & Misic (2011)	Socially Responsible Design	Considering the needs and values of various stakeholders beyond the conventional triple bottom line.
Tischner & Charter (2017)	Promoting Sustainable Design	Underlines the importance of cooperation among stakeholders in achieving sustainable design.

Table 1 presents sustainable design approaches and theories clearly and concisely. It highlights the diverse perspectives and methodologies that contribute to the development of sustainable design practices.This section synthesizes a range of sustainability frameworks and principles and illuminates their intricate implications in the design field. It presents a nuanced understanding of sustainability, underscoring the evolving role of designers in confronting and navigating the complex challenges of sustainability. This exploration reveals how frameworks like the Triple Bottom Line, Cradle to Cradle, and systems design principles serve as more than mere guidelines; they represent a paradigm shift in how designers approach product and system development.

The insights gleaned from various studies, such as those by Ceschin and Gaziulusoy (2016) and Ilieva et al. (2022), highlight the shift from traditional, linear design approaches to more holistic, systems-oriented methodologies. These methodologies are about creating environmentally friendly products and rethinking the entire lifecycle and the system within which these products operate. This approach is critical in addressing the interconnected nature of today's global sustainability challenges.

Furthermore, the section emphasizes the importance of a multi-faceted approach in design, integrating considerations of efficiency, waste reduction, and social responsibility. As discussed by Ilieva et al. (2022), the concept of biomimicry exemplifies this by drawing inspiration from nature, not only in aesthetics but also in functionality, resilience, and sustainability.

Additionally, the research underscores designers' need to engage in collaborative and interdisciplinary efforts. Blizzard and Koltz (2012) noted that achieving sustainable design outcomes requires a comprehensive understanding of and interaction with various systems, stakeholders, and disciplines. This collaborative approach is essential in creating designs that are not only innovative but also responsible and sustainable in the long term.

In essence, this section enriches our understanding of how sustainability is integrated into design, emphasizing the critical role of designers in leading the charge toward a more sustainable future. It calls for a departure from traditional design practices, advocating for a more conscious, comprehensive approach considering the full spectrum of environmental, social, and economic impacts. The insights provided here are pivotal in guiding future designers and researchers in pursuing sustainable solutions, highlighting the need for continued innovation and collaboration in this ever-evolving field.

The Designer's Role in Sustainable Product Design (Theme 2)

A variety of implications for design practice emerge from the use of sustainability frameworks and concepts. The design process choices significantly impact a product's sustainability, encompassing everything from raw material sourcing to product disposal.

Armstrong and Le Hew (2011) examined the constraints that the current social paradigm, which prioritizes economic growth and consumerism in the apparel industry, places on sustainability. They set guidelines for developing sustainable garment products and contend that a new paradigm focuses on sustainability, social justice, and well-being. These values improve the well-being of stakeholders, encourage social equality, and lessen the harmful effects of products on the environment. They contend that the garment business should promote sustainability and well-being as part of a shift toward a new dominating social paradigm.

It is imperative to shift from a linear to a circular economy, as emphasized by Bocken et al. (2016). The article offers essential guidance on modifying product design and business models to facilitate this transition. The authors assert that a circular economy, in which products and resources are reused and recycled, is necessary to achieve long-term sustainability. They claim that the existing linear production, consumption, and disposal model is unsustainable. They advise companies and product designers to reconsider their strategies to enable this transformation. In pursuit of long-term sustainability, the article underlines the significance of incorporating circular economy principles into product design and business strategies. It suggests that designers and companies modify their methods and illustrate effective circular techniques.

Approaches and Strategies for Sustainable Product Design: Much has been investigated on sustainability, its guiding principles, and how they apply to industrial design. The difficulties that designers face when implementing "sustainable product-service systems" are covered by Vezzoli et al. (2015). The authors list three significant challenges to be overcome:

- the need for a more comprehensive, systems-based approach to PSS design that considers the entire lifecycle of a product or service;
- the need for new business models and collaborations that consider PSS economically viable and sustainable; and
- the need for increased collaboration and communication between stakeholders in the design and implementation of PSS.

According to the authors, solving these difficulties requires a more collaborative and participatory design strategy involving stakeholders from all phases of the product's lifetime, such as suppliers, manufacturers, consumers, and recyclers. Additionally, they emphasize the necessity of frameworks for policy and regulation that promote long-term PSS and the significance of considering the social and cultural contexts in which PSS are implemented.

Wat and Hallstedt (2022) have formed and evaluated a profile model that may be utilized to manage sustainability integration into design requirements during product development. The model includes a set of evaluation techniques that may be employed to assess a product's sustainability performance as it is being developed and a set of sustainability criteria that may be tailored for particular items.

Two case studies were conducted to test the approach. The first case study involved a toy designed for children, while the second case study focused on a product for food packaging. The authors concluded that one assisted the development teams in effectively incorporating sustainability into their design choices. The research emphasizes the crucial role of integrating sustainability into the product development process right from the outset. It offers insights into applying the profile framework to promote sustainable product development. The necessity for interdisciplinary cooperation and the trade-offs between environmental, social, and economic concerns are a few difficulties with implementing sustainable design approaches. Overall, the paper offers insights for designers and product development teams seeking to integrate sustainability into their design processes.

A framework for designers and businesses to incorporate sustainability into their product development procedure is offered in the chapter of the book by Tischner and Charter (2017). The authors discuss the concept of sustainable product design. The process of developing products that minimize environmental impact while meeting user requirements and expectations is described. The chapter underlines the significance of paying attention to a product's complete life cycle, from the extraction of raw materials through disposal, and argues how designers should use systems thinking in their work. Furthermore, the authors guide particular tools and techniques that may be employed to incorporate sustainability into the product development process for each stage. A comprehensive and cooperative approach to sustainable product design may assist designers and businesses in resolving these challenges. The chapter offers designers and companies seeking to incorporate sustainability into their product development process a complete overview of sustainable product design and valuable guidance.

The use of digital technologies to support sustainable product management in a circular economy context is studied by Rusch, Schöggl, and Baumgartner (2022). The authors begin by providing an overview explanation of the circular economy idea, which aims to reduce waste and resource consumption by extending the useful life of things. The authors then review how digital technologies, including product lifecycle management systems, blockchain, and artificial intelligence, might assist with sustainable product management in a circular economy. The use of digital technologies in sustainable product management presents several difficulties discussed in the article, including the necessity for data privacy and security, the risk of new waste and pollution forms due to technology, and others.

These studies emphasize the significance of sustainable product design and offer information on the frameworks and guiding principles for sustainable design (Table 2). They also point to the necessity for continuing study and

innovation in this field, particularly in underdeveloped nations where sustainable design may play a significant role in poverty reduction and sustainable development.

Table 2. The Significance of Sustainable Product Design (from selected sources)

Authors	Key Focus	Implications for Design Practice
Armstrong & Le Hew (2011)	Sustainability in Apparel Industry	Shift focus to sustainability, social justice, and well-being. Encourage social equality and reduce environmental harm.
Bocken et al. (2016)	Circular Economy	Modify product design and business models for sustainability. Integrate circular economy principles.
Vezzoli et al. (2015)	Sustainable Product-Service Systems (PSS)	Collaborative and participatory design strategies. Policy frameworks and consideration of social-cultural contexts.
Wat & Hallstedt (2022)	Sustainability Integration in Product Development	Integrate sustainability from the outset of product development. Manage trade-offs between environmental, social, and economic aspects.
Tischner & Charter (2017)	Sustainable Product Design Framework	Systems thinking and specific tools for each stage of product development. Comprehensive and cooperative approach.
Rusch, Schöggl, & Baumgartner (2022)	Digital Technologies in Circular Economy	Utilize digital technologies for sustainable management in a circular economy. Address associated challenges.

Challenges and Opportunities for Sustainable Product Design (Theme 3)

Ahmad et al. (2018) discuss the obstacles that must be addressed when creating sustainable products. The challenges in the researchers' assessment are:

- Complexity: Engineering, design, and business are just a few disciplines in developing sustainable products, rendering them complicated and challenging to manage.
- Lack of standards: It is challenging to determine and evaluate the sustainability of various products due to the need for internationally recognized standards for sustainable product design and development.
- Cost: Sustainable products are challenging to justify since sustainable materials and manufacturing techniques may be more expensive than conventional ones.
- Consumer behavior: It is challenging to defend the investment in developing sustainable products when consumers are not prepared to pay more.
- Short product life cycles: It is challenging to justify the investment in sustainable product design and development due to the short lifespan of many items, as the advantages might only be realized after the product becomes obsolete.
- Limited availability of sustainable materials: Using sustainable materials in product design and development is challenging due to their limited availability.
- Lack of awareness and education: There is a need for more information and instruction among stakeholders, including designers, manufacturers, and consumers, on the significance of sustainable product design and development.

Chandrasegaran et al. (2013) provide an overview of the evolution, challenges, and prospects of knowledge representation in product design systems. The requirement for integrating various types of knowledge, data scarcity, complexity, and uncertainty are only a few of the

challenges presented in knowledge representation for product design.

The obstacles and opportunities for SCP in Asia are discussed by Tseng, Tan, and Siriban-Manalang (2013), along with the requirement for further awareness and instruction on sustainable behaviors, the importance of policy and regulation, and the possibility for environmentally friendly innovation and technology. Moreover, many case studies of environment-conscious design and practice are presented in the article, including creating eco-friendly products and packaging, using renewable energy sources, and adopting environmentally friendly manufacturing methods.

Trevisan et al. (2013) introduce the Design Buckles framework in their article, which consists of six categories of design parameters: function, technology, material, user, value, and organization. These categories identify opportunities for the eco-design of PSS, such as increasing product lifespan, reducing material waste, and improving user engagement.

Table 3. Challenges and Opportunities of Sustainable Product Design (from selected sources)

Challenges	Opportunities
Balancing sustainability with profitability	Reducing environmental impact through sustainable design practices
Integrating sustainability considerations throughout the design process	Creating innovative and more sustainable products and services
Ensuring that sustainability efforts are effective and measurable	Incorporating circular economy models and closed-loop systems
Addressing the trade-offs between different sustainability criteria	Reducing resource use and waste throughout the product lifecycle
Encouraging consumer demand for sustainable products	Increasing consumer awareness and demand for sustainable products
Addressing the potential for unintended consequences in sustainability efforts	Collaborating with stakeholders to drive sustainability efforts forward

The Impact of Sustainable Product Design on Society and the Environment (Theme 4)

The review found that sustainable product design can significantly impact society and the environment. Creating sustainable products is a powerful way to reduce greenhouse gas emissions, conserve natural resources, and limit waste and pollution.

Mazar and Zhong (2010) explore the relationship between using green products and ethical behavior. The researchers conducted experiments to determine if individuals who use eco-friendly products are prone to act ethically compared to those who use standard products. Moreover, Norgate and Haque (2010) explore the environmental impact of mining and mineral processing operations. According to the research, energy use and greenhouse gas emissions from mineral processing and mining operations are considerable and vary depending on the type of mineral and the particular operation. The authors propose that by making operations more effective and by utilizing renewable energy sources, the mining industry might lessen its environmental impact.

Design researchers highlight the significant impact sustainable product design would have on society and the environment since sustainable product design has the potential to improve the quality of life of individuals and communities. To illustrate, Dangelico and Pujari (2010) explore the integration of environmental sustainability into product innovation by companies. The authors identified companies' motives and approaches to integrating green product innovation into their operations. The article emphasizes the importance of mainstreaming green product innovation to reduce the environmental impact of products and promote sustainable development (Dangelico & Pujari, 2010).

One of the most significant impacts of sustainable products designed to be more energy-efficient, durable, and easy to repair can contribute to a more sustainable and equitable future. Bracquene et al. (2019) search for the development of a methodology to evaluate the repairability of energy-related products and provide a detailed overview of the methodology for evaluating repairability, including the criteria used to evaluate repairability and the scoring system used to rank products. Moreover, they discuss the limitations of the methodology and potential areas for improvement.

Cordella et al. (2021) explore the technical aspects of the durability of smartphones, including reliability and repairability. They conducted a study to evaluate smartphones' design and manufacturing practices and identify areas for improvement to increase their durability. Accordingly, smartphones frequently fail due to their intricate designs and advanced technologies, which makes repairs challenging and pricey (Cordella et al., 2021). The study claims that making smartphones more repairable may reduce their environmental effect and promote sustainable development.

Cherian and Jacob (2012) surveyed consumers to investigate the factors influencing their purchase of environmentally friendly products and their awareness of green marketing. The researchers emphasize the value of understanding consumers' feelings toward environmentally friendly products and the efficacy of green marketing techniques. As a result, they argue that marketing the environmental benefits of a company's products could be profitable and that consumers may support sustainable development by purchasing environmentally friendly goods (Cherian & Jacob, 2012).

Table 4. The Impact of Sustainable Product Design on Society and the Environment

Author(s)	Study Focus	Key Findings
Mazar and Zhong (2010)	Relationship between using green products and ethical behavior	People who use green products are more likely to behave ethically than those who use conventional products
Norgate and Haque (2010)	Environmental impact of mining and mineral processing operations	Energy use and greenhouse gas emissions from mineral processing and mining operations are considerable
Dangelico and Pujari (2010)	Integration of environmental sustainability into product innovation by companies	Mainstreaming green product innovation can reduce the environmental impact of products and promote sustainable development.
Bracquene et al. (2019	Development of a methodology to evaluate the repairability of energy-related products	More energy-efficient, durable, and easy-to-repair products can create a more sustainable and equitable future.
Cordella et al. (2021)	Technical aspects of the durability of smartphones, including reliability and repairability	Making smartphones more repairable can reduce their environmental impact and promote sustainable development.
Cherian and Jacob (2012)	Factors that influence the purchase of environmentally friendly products and awareness of green marketing	Marketing the environmental benefits of a company's products can be profitable, and consumers may support sustainable development by purchasing environmentally friendly goods

Table 4 provides empirical evidence of the impacts of the current research on sustainable design and their key findings. According to the current research and findings, developing sustainable products has the potential to benefit society and the environment. So far, it is essential to be aware of the difficulties and limitations related to producing sustainable products and to make an effort to overcome them throughout the design process. By incorporating sustainability frameworks and concepts into design practice, designers may contribute to developing a more sustainable and equitable future.

DISCUSSION AND CONCLUSION

In an era where environmental concerns are paramount, the imperative to transition from a linear to a circular economy emerges as a cornerstone for achieving enduring sustainability. This transformative shift calls for a fundamental reevaluation of our existing production, consumption, and disposal models, advocating for a paradigm where resources and products are continually reused and recycled. Integral to this transformation are the roles of businesses, product designers, and industrial designers, each contributing uniquely to cultivating a sustainable culture.

Industrial design stands at the forefront of this shift, tasked with crafting products that mitigate adverse environmental, economic, and social effects. By designing recyclable or reusable products that consume fewer resources and are made from sustainable materials, industrial designers lay the groundwork for a more sustainable product lifecycle. Their work extends beyond environmental considerations to address social and economic challenges, such as creating employment opportunities in developing nations or enhancing accessibility for people with disabilities.

Parallel to this, designers play a pivotal role in integrating sustainability into their creative process. This encompasses all aspects of design, from sourcing raw materials to the eventual disposal of the product. Designers are creators and influencers who can establish new norms in industries, shifting focus from traditional economic growth and consumerism to paradigms rooted in sustainability, social justice, and overall well-being. The transition from a linear to a circular economy is significantly fueled by designers' commitment to embedding principles into their work, thereby contributing to the longevity and sustainability of the products and resources they create.

Companies in this sustainable ecosystem are not mere bystanders but active participants. Their impact on society and the environment through sustainable product design is profound. By incorporating environmental sustainability into product innovation, companies can significantly reduce their ecological footprint – cutting down greenhouse gas emissions, conserving natural resources, and limiting waste and pollution. The implications of such sustainable practices extend beyond environmental benefits; they enhance the quality of life for communities and individuals and play a critical role in driving

sustainable development. Companies that embrace green product innovation set the stage for mainstreaming sustainable practices in their operations, thus reinforcing a commitment to a sustainable future.

This journey towards sustainable product design, however, has its complexities. The transition entails overcoming economic barriers, such as the costs associated with sustainable materials and production methods. It demands an inclusive approach that considers sustainable design's broader economic and social ramifications, ensuring its affordability and accessibility for diverse consumer groups. Moreover, embedding sustainability into the core of design education emerges as a crucial step, equipping future designers with the necessary skills and knowledge to navigate this landscape.

Table 5. The Role of Industrial Design and Designers in Creating Sustainable Culture

Role of Industrial Design and Designer	**Explanation**
Design for sustainability	Designers might limit energy and waste production, utilize eco-friendly materials, and create things that may be disassembled apart and recycled.
Lifecycle thinking	Designers must consider the environmental impact of a product from start to finish, including materials used and disposal/recycling.
User-centered design	In order to develop products that are simple to use, fix, and maintain, designers should interact with people to understand their needs and behaviors.
Social responsibility	Designers might consider how their designs affect community involvement, worker safety, and fair labor practices.
Collaboration	Designers may collaborate with other stakeholders to develop sustainable solutions that benefit individuals and the environment, including engineers, manufacturers, and legislators.
Innovation	Designers can go beyond the existing boundaries and create cutting-edge solutions and products that outperform efficiency, effectiveness, and sustainability compared to the current standards.

In conclusion, the collective efforts of industrial designers, product designers, and companies are indispensable in forging a sustainable future. Their diverse contributions, ranging from creating sustainable products to influencing consumer behavior and operational paradigms, are the keystones in the architecture of a sustainable culture. Their insights and innovations are responses to environmental challenges and proactive steps toward a more equitable, sustainable, and inclusive world.

Bu bölüm, alt başlıklara bölünebilir. Deneysel sonuçların, bunların yorumlarının ve çıkarılabilecek deneysel sonuçların kısa ve kesin bir tanımını sağlamalıdır. Bu bölüm alt başlıklara bölünebilir. Deneysel sonuçların, bunların yorumlarının ve çıkarılabilecek deneysel sonuçların kısa ve kesin bir tanımını sağlamalıdır. Bu bölüm alt başlıklara bölünebilir. Deneysel sonuçların, bunların yorumlarının ve çıkarılabilecek deneysel sonuçların kısa ve kesin bir tanımını sağlamalıdır. Bu bölüm alt başlıklara bölünebilir. Deneysel sonuçların, bunların yorumlarının ve çıkarılabilecek deneysel sonuçların kısa ve kesin bir tanımını sağlamalıdır.

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