

Changing products through new advancements in design

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The present article discusses the importance of new processes, emerging materials, and new technologies as key strategies for conceiving, designing, and producing innovative products and systems. Over the past decade, advancements in these fields have significantly influenced how products and systems are conceptualized and designed, impacting the entire value chain and the methods for creating and changing business models. This transformation enables speculation and the crafting of new artifacts and future scenarios by altering how products are developed, upgraded, and updated, offering benefits in idea creation, experimentation, testing, and sustainability. The article presents the main topics through the subjects of the papers submitted to the track “[CHANGING] Products and Production”. In this regard, it will delve into themes such as, but not limited to, new aesthetics and functions in product design, AI, haptic and wearable technologies, bio-fabrication.

Keywords: *design processes; speculative design; emerging technologies and materials; design innovation*

1 Design-driven product and process innovation

In the past decade, the relentless progression of innovative manufacturing processes has had a profound influence on the way we approach the conceptualization, visualization, and design of novel products and systems. These processes exert their influence across the entire spectrum of the value chain, spanning from fundamental research to the final stages of product development and delivery. More specifically, the widespread adoption of digital fabrication and digital craftsmanship tools and technologies is fundamentally reshaping our approach to how we create, enhance, and keep our products up-to-date.

These advancements offer substantial support for generating new ideas and concepts. They also enhance the value of tools applicable to experimentation, fostering testing opportunities that range



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from the early stages of prototyping to the final marketplace. Moreover, they bestow a critical competitive edge, particularly in terms of sustainability.

These innovative manufacturing processes empower us to engage in forward-thinking speculation and the envisioning of novel materials, artifacts, and future scenarios, all viewed through the lens of sustainability. In this transformative landscape, the potential for crafting a sustainable and forward-looking perspective on future product and system developments is considerable.

The article provides an introductory overview of the track "[Changing] Products and Production," which encompasses a collection of contributions delving into the pivotal role that design practice and research play in the process of envisioning and speculating about the future of products and production. Within this comprehensive track, four distinct sub-topics have been organized to structure the exploration effectively. These sub-topics include:

Emerging Materials: This category focuses on the examination of innovative materials that are currently emerging thanks to digital fabrication, digital craftsmanship and bio-fabrication processes and applications, and a renewed interest natural science. These materials have the potential to revolutionize traditional design and production methods. The contributions in this sub-topic aim to analyse the implications and possibilities presented by these ground-breaking materials.

Product Design Innovation: Within this sub-topic, the track explores how design innovation is shaping the evolution of products. It delves into various aspects of product design, such as novel concepts, aesthetics, functionality, and user experience. The contributions here delve into the innovative strategies and approaches employed to redefine product design.

Healthcare: The healthcare sub-topic investigates the intersection of design and healthcare. It explores how design principles and methodologies are being applied to enhance healthcare products, services, and systems. The contributions in this category shed light on the transformative impact of design in specific healthcare settings, such as elderly, menopausal women, chronic diabetes, and global pandemics.

Design Process Innovation: This sub-topic delves into the innovative approaches and methodologies employed in the design process itself. It explores how advancements in design processes are contributing to more efficient, sustainable, and creative approaches to product development. The contributions aim to uncover the evolving landscape of design processes.

Through these distinct sub-topics, the track endeavours to provide a comprehensive understanding of how design, research, and innovation are shaping the future of products and production across various domains and industries.

2 Trajectories in changing product and production

2.1. Emerging Materials

In the last two decades, materials have become increasingly important in design practice, fuelling innovation, and adding value to products and systems. From a traditional/engineering and chemical point of view dealing with a material means select and choose the right one for technical purposes. (Ashby et al 1993; Ashby and Johnson 2013).

Nevertheless, scholars in the design discipline have established new approaches and methods to design with and for materials. From this lens, a material can be selected but also designed and envisioned to achieve certain performances, aesthetics, and sensorial qualities (Rognoli, 2004; Rognoli, 2010; Karana et al. 2008).

This perspective is allowing the rise of new emerging materials characterized by a higher level of complexity than the traditional ones. Indeed, nowadays, the panorama of materials is enriched by new materials likewise smart materials, bio-based and growing materials, nanomaterials, recycled materials from organic resources, etc.

Such materials open several opportunities for designers such as manipulate and develop material in multiple ways, e.g., tinkering, (bio) fabricating, growing, and cooking. In this sense, a designer explores different opportunities that the material can exploit, with trials and errors, obtaining successes and failures.

The “Emerging Materials” session unfolds several interesting insights regarding what was mentioned above, highlighting the importance of digital fabrication in applications other than materials.

“Forming Bacterial Cellulose: a research activity exploiting digital fabrication technologies” develops from the consideration of the need for innovative production models that address environmental and social concerns, emphasizing the limitations of existing production systems and the role of technology, particularly Digital Fabrication Technologies (DFTs) such as Additive Manufacturing (AM), in enabling sustainable production. The contribution explores the potential of bio-fabrication, specifically Growing Materials (GMs), and the use of Bacterial Cellulose (BC) in sustainable production. It also discusses the integration of DFTs and BC in the production process and provides a reflection on experiments aimed at changing how BC is designed and used in production, potentially revolutionizing industrial design practices.

“From Bio-inspired Design to Microbiology-inspired Design: A Conceptual Model-based Case Study on Biological Materials Informed by Emotions” focuses on the integration of natural and biological elements into the design process, discussing biophilia, biophilic design, bio-inspired design, and bio-design, which all incorporate aspects of nature and biology. The study aims encompass understanding emotional responses to biological materials in everyday design, creating a conceptual model for these materials' purposes, and experimenting with biomaterial-based furniture design. Its findings highlight that emotional responses to biomaterials are influenced by aesthetics and design, and the proposed conceptual model aids in understanding the purposes of biomaterials in everyday designs.

“Exploring the Design Applications of Key Emerging Materials from Natural Sciences Through a Design Ideation Workshop” observes how the design field is evolving towards incorporating living and adaptable aesthetic and functional elements while exploring alternatives found in nature. In fact, designers, architects, and artists are proposing the use of emerging materials from synthetic biology, bionics, chemistry, and material science to create new design possibilities that embrace natural aesthetics and functionalities. However, designers often lack knowledge about applying these materials in product design due to three main obstacles: a lack of understanding regarding their potential applications, limited creativity stemming from established design solutions, and the confines of traditional product design processes. This study conducted a design ideation workshop with

graduate students to address these challenges and uncover opportunities for innovative product designs using emerging materials with dynamic features.

“Co-creation through digital fabrication technology: A systematic review” discusses digital fabrication's role in modern society, emphasizing its foundation in shaping tangible ideas through computer-controlled machines. It highlights how digital fabrication tools enable various individuals, including designers, students, and developers, to create product prototypes. The text explores the emergence of makerspaces and Fab Labs, explaining their alignment with collaborative principles and their role in user-driven prototype development. Furthermore, it discusses the adoption of digital fabrication in education, emphasizing its contribution to teaching 21st-century skills and its applications in different industries. The text underscores the connection between design and digital fabrication and introduces the concept of co-creation, particularly in makerspace-based projects. It also outlines the research focus on understanding how co-creation manifests in digital fabrication within makerspaces. Finally, it provides insights into the results of the analysis, including the publication trends and prevalent themes such as co-design, collaboration, and tinkering in the context of digital fabrication.

Finally, “Design Principles for a Workshop Using 3D Food Printers: Participatory Digital Food Design Research” discusses the expanding field of food design and its academic framework, highlighting the growing importance of addressing food-related challenges such as climate change and population growth, and connecting the opportunities offered by emerging technologies like 3D food printing towards a sustainable food production. The study reviews existing research, particularly in technology-driven food design and participatory approaches involving non-professionals. It presents a workshop that uses 3D food printers to envision future foods, addressing challenges related to technology accessibility, and explores future scenarios to envision food from a user-centric perspective.

2.2. Product design innovation

Design is a critical field that fosters innovative product creation and positively impacts a company's operational environment. Unlike innovation driven solely by technology, design influences users directly through elements such as form, colour, material, and interaction, making products appear more appealing to consumers and evoking a desire to possess them. Furthermore, design adds value to products for users, allowing manufacturers to secure competitive advantages by fostering consumer loyalty and commanding higher prices rather than solely focusing on reducing production costs. Additionally, well-designed products instil a sense of pride in ownership among users as they interact with the product.

This sub-topic presents innovative solutions in different sectors and evaluation of different product design aspects and approaches to promote innovation.

The first topic explores how user value generated through design differentiation influences pricing decisions. Our second topic revolves around a parametric design method to achieve a unified "family look" for high-speed train head designs and developing a mathematical model to assess these designs. The third topic focuses on designing temporary emergency shelters made from cardboard that can be fabricated and assembled in disaster-stricken areas. Finally, the fourth topic investigates how product softness and weight perception can evoke positive emotions in users.

“Raising The Ceiling: The Impact Of Design-Based Differentiation On Product Pricing” aims to elucidate how design-based differentiation influences perceptions of product pricing.

Many manufacturing companies strive to reduce production costs to gain an edge in price competition, often leading to conflicts between entrepreneurs and designers (Liozu, 2019). However, successful design-driven companies refrain from competing by lowering production costs (Walsh & Roy, 1985). From this perspective, it is essential to introduce an appropriate method for designers to explain how design-based differentiation influences pricing decisions for entrepreneurs.

This study, using data from consumer surveys in the athletic footwear industry, discusses the User Value and the Willingness to Pay (WTP) concepts and offers insights into how consumers evaluate the value of design-based differentiation in new products.

“Head shape design of Chinese 450 km/h high-speed trains based on pedigree feature parameterization” presents the case of the China Railway Rolling Stock Corporation (CRRC) facing challenges in establishing a unified family style for their high-speed trains due to various brand influences. With the development of 450 km/h high-speed trains in China, this study developed a pedigree feature parameterization-based design method for high-speed trains. It involved calculating similarities between different CRRC train head shapes, dividing them into four feature areas, and defining control parameters for each area. By predicting parameter values through regression analysis, this method successfully achieved parametric train shape prediction, contributing to the creation of a unified design strategy for CRRC high-speed trains.

An intriguing aspect of this research is its ability to design various train head shapes using 12 key design parameters that determine the train head's form. In other words, this study's results suggest that by extending the design parameters, it might be possible to automatically generate innovative designs that satisfy users regarding functionality, usability, and emotional aspects using computer-aided design.

“Prototyping A 7-Meter Frameless Dome as Emergency Shelter: Test Build Viability and Devise Team Strategies” focuses on sheltering as prioritized disaster relief efforts, which can vary from temporary to permanent solutions. The study moves from three premises: 1. Traditional donor-provided shelters are costly and slow, while mass sheltering often lacks privacy and sanitation; 2. Displaced communities often prefer small-scale, self-built, on-site shelters, promoting self-reliance and local economic support. 3. On-site construction isn't always feasible. Therefore, it explores a hybrid approach by planning off-site and building on-site, focusing on temporary sheltering (less than two weeks). It introduces digital fabrication to enhance on-site sheltering, prototyping a 7-meter geodesic dome as an emergency shelter, demonstrating how this approach offers quick setup/takedown, local fabrication, and community engagement, aligning with international sheltering recommendations.

“Exploring the Effect of Softness and Weight of Materials on Positive Emotion Regulation: A Case Study of LEGO” explores the relationship between touch experiences and positive emotion regulation, focusing on texture and weight perception. The study examined how touch variables, like softness and weight in LEGO blocks, influence positive emotions. This research can inform product development, especially for tactile experiences, potentially positively impacting on various industries, like toys and stationery as designers can benefit from empirical material perception insights.

The topics discussed in this session revolve around how to apply these research findings to practical design. The first paper identified the range of product prices based on design differentiation. It assessed the related user values, often expressed in abstract terms such as Significance and Spiritual Values. To achieve these values, how should designers apply design elements? Practical methods for achieving this need to be developed. The second study suggests that parameter-based design can help designers develop consistent designs. However, a discussion on identifying such parameters should also be considered if designing entirely new products.

Additionally, we can discuss how AI designers and parametric design can contribute to design innovation. The third paper effectively conveys valuable knowledge and information for designing Geodesic dome-shaped temporary emergency shelters. However, there remains a question as to why a Geodesic dome shape is necessary. There may be a need for a discussion on alternative shelter shapes that are easier to manufacture and assemble. Finally, in the last paper, if we can assert that new experiences related to novelty trigger positive emotions, it is worth discussing whether eliciting such emotions holds significance for products that have been used for an extended period. Additionally, we should consider what user experience elements, beyond LEGO, can serve as novelty factors.

2.3. Healthcare

In recent years, the term care has extended from curating diseases and specific pathologies to prevention and overall well-being, blurring the borders of medical and non-medical support (Kale et al., 2016). In this sense, healthcare is not limited to the clinical domain but extends to everyday tasks and reminders to enhance a healthy lifestyle.

More in detail discussing the intersection between design and healthcare means taking on a patient/user-centred approach and dealing with new systems connected with healthy lifestyle choices, being physically active and eating healthily, avoiding unhealthy lifestyle habits and active ageing.

Moreover, there has been a pronounced surge in the convergence of digital technologies and innovative design methodologies within the realm of healthcare.

Digital technologies have tremendous potential to improve healthcare conveyance by improving adequacy, proficiency, availability, and personalization. Various digital solutions have been developed to empower patients to adopt and sustain healthy lifestyle choices or to support people in old age and promote healthy ageing.

On the other side, new technologies, devices, and the Internet of Things (IoT) ensure accessible care to a wider population (Kolodner et al., 2008) while improving the management of remote care to patients and caregivers (Awadalla et al., 2021; Kor et al., 2016; Cortez, 2018; Varshney, 2005).

This sub-topic includes a wide range of researches that demonstrate the potentiality for design innovation in very specific applications in healthcare, at the scale of niche markets as well as at the global level.

“Assessing a Mobile and Modular Negative Pressure Ward (Mobile Clinic Module) for COVID-19 Outpatient Treatment” starts from the consideration that the recent surge in demand for healthcare facilities during infectious disease pandemics, such as COVID-19, underscores the critical role of

mobile negative pressure units in hospitals. Nevertheless, there is a scarcity of information regarding their decision-making, setup, operation, and removal, as well as their impact on patients and medical and management personnel. The study investigates issues arising from implementing negative pressure mobile clinic modules in real hospital settings and assesses their effectiveness, identifying usability, efficiency, stability, and cost-effectiveness challenges when used as outpatient treatment centres. Design and technological enhancements are also discussed to improve unit performance and ensure safe medical environments for infectious disease patients, promoting systematic understanding and practical recommendations for successful implementation in real hospitals.

Two contributions offer insight in regard of elderly healthcare.

“Toward More Considerate Designing of Home Exercise Equipment for Older Adults: A Qualitative Analysis of the Specific Needs and Challenges of Older Adults for Physical Exercise” moves from the analyses of elderly’s health issues, in particular in Korea. The deterioration of physical condition and associated health issues among older adults presents a significant challenge, with exercise offering a viable solution. This research endeavours to investigate the essential factors integral to the design of home exercise equipment tailored to the needs of older adults. It proposes design concepts specifically tailored to address these considerations, providing valuable guidance for the design and evaluation of exercise equipment catering to the unique requirements of older adults.

“Dynamic Personalities for Elderly Care Robots: User-Based Recommendations” presents the emerging elderly care robots solutions as supporting tools to provide physical assistance to this growing population segment. It explores the development of dynamic personalities in elderly care robots to enhance communication and address the evolving needs of seniors.

“Analysis of the Menotech and Femtech Markets for Menopausal Women in Japan” tackles another challenge, the support of menopausal women, in a specific market, Japan, in relation demographic issues and their economic and gender gap implications. Through a comprehensive analysis of the domestic and international Menotech markets, it proposes fostering innovation in product development and services, disseminating knowledge, and leveraging Menotech communities and associations as essential strategies to facilitate the growth of the Japanese Menotech market and the wider adoption of Menotech services.

“AI Logic of Care: premises for upgrading the smart bandages for diabetic chronic wounds” explores the correlation between medical application design and the “logic of care” in the context of smart bandages for diabetic wounds, introducing the “AI logic of care” framework that promotes a comprehensive and interdisciplinary approach to prototyping, aiming to bridge gaps in care-centric design research in smart bandages, and advance transformative treatment solutions.

2.4. Design process innovation

This forth sub-topic encompasses a diverse range of papers addressing critical facets of design innovation. These papers shed light on previously underexplored dimensions of design processes and offer fresh insights.

“Differences in the use of analogies by designers at different stages of conceptual design” focuses on the use of analogies in the conceptual design process, which has been relatively understudied. It divides the analogical design process into three stages: concept exploration, concept development, and concept forming. The research distinguishes between analogy tasks and design tasks, finding that

analogies are predominantly used in the early stages of problem definition and concept exploration and gradually decrease in later stages. These findings challenge previous notions and provide valuable insights for design education, emphasizing the dynamic nature of analogy utilization throughout the design process.

“Haptic aesthetics in product design: designing headphones that feel beautiful” explores the application of aesthetic theories to the haptic qualities of headphones, focusing on MAYA (Most Advanced Yet Acceptable) and Unity-in-Variety (UiV) principles. It addresses the neglect of haptic emotions and aesthetics in product design despite their importance in consumer preferences. Over-ear headphones were chosen as the object of study due to their daily use and rich haptic interactions. The study led to the design of a concept headphone that balanced haptic novelty and typicality while embodying UiV principles. Findings indicate that haptic novelty, typicality, unity, and variety play crucial roles in haptic aesthetics but also emphasizes the need to consider time, comfort, and multi-sensory interactions in haptic design.

“Shifting Spaces in Fashion: Approaching digital design spaces from a physical perspective” discusses the impact of digital technology, specifically XR technology, on fashion design processes. Historically, fashion designers were trained in analogue skills, but there's a shift towards digital alternatives for sustainability. XR technology, including VR and AR, is explored as a mediator and transformer of design spaces, challenging the traditional binary view of digital and physical realms. The study highlights a physical-digital spectrum, not a strict division, and suggests the need for better compatibility between technologies, designer training for digital processes, and solutions for tactile feedback. Ultimately, this approach reintroduces physical engagement into digital fashion design, fostering creativity and diverse design experiences.

Finally, “Designing Ambi-Bracelet - an Interactive Bracelet for Ambient Communication between Partners” introduces the Ambi-Bracelet, a novel communication device concept designed to support emotional connections over a distance. It addresses the limitations of conventional communication technologies in mediating emotions and connectedness, especially during the Covid-19 pandemic, which increased the risk of loneliness. The research builds upon the concept of smart jewellery and technology-mediated emotional communication, aiming to enhance affective connections between distant loved ones. The design leverages 3D modelling, 3D printing, and electrochromic displays, offering a cost-effective and highly customizable solution.

3 Reflection and conclusions

Through the analysis and synthesis of insights presented in the papers of the four sessions, various trends and recurring themes can be identified. These includes the use of new advanced technology, advanced manufacturing, new materials, and processes.

The submitted papers provide a comprehensive overview of the change that is impacting the realm of industrial design and production.

Since its inception, industrial design has undergone profound transformations.

Industrial design is defined as “the professional practice of creating products used daily by millions of people worldwide. Industrial designers go beyond the product's aesthetics, also focusing on functionality, manufacturing processes, and the overall value and user experience it delivers”¹.

Today, designing industrial products entails more than just addressing form, function, or specific manufacturing procedures for a particular industry. It involves crafting comprehensive systems and user experiences, incorporating state-of-the-art technologies, and harnessing innovative manufacturing methods. In our contemporary world, we are constantly pervaded by cutting-edge technologies that continually reshape our lifestyles and our perception of the world around us. These technological advancements drive innovation across diverse product categories and influence how people interact with each other, while also playing a defining role in shaping the behaviour of objects, environments, and systems (Forlizzi, J. & Battarbee, K.; 2004).

The emergence of digital technologies is transforming the field of design, necessitating that both designers and researchers acquire expertise in these technologies to effectively shape them and create meaningful and captivating experiences for end-users.

Additionally, manufacturing methods have changed as well, particularly due to the proliferation of advanced manufacturing. Advanced manufacturing leverages cutting-edge technologies, including digital tools, to generate innovative products, spanning from basic to intricate, while enhancing processes to reduce waste, pollution, material consumption, and energy consumption².

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¹ <https://www.idsa.org/about-idsa/advocacy/what-industrial-design/>

² <https://ec.europa.eu/digital-single-market/en/news/advancing-manufacturing-advancing-europe-report-task-force-advanced-manufacturing-clean>

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