sustainability

MDPI

Article

Circular Economy in Industrial Design Research: A Review

Kirsten van Dam [1,*], Luca Simeone [2,*], Duygu Keskin [3], Brian Baldassarre [4], Monia Niero [5] and Nicola Morelli [2]

1 Out Of Office, Design & Innovation, Halgreensgade 16, st. th., 2300 Copenhagen, Denmark
2 Department of Architecture, Design and Media Technology, Aalborg University, A. C. Meyers Vænge 15, 2450 Copenhagen, Denmark; nmor@create.aau.dk
3 Department of Industrial Engineering & Innovation Sciences, Eindhoven University of Technology, P.O. Box 513, 5600 MB Eindhoven, The Netherlands; d.keskin@tue.nl
4 Faculty of Industrial Design Engineering, Delft University of Technology, Landbergstraat 15, 2628 CE Delft, The Netherlands; b.r.baldassarre@tudelft.nl
5 Department of Planning, Section for Sustainable Design and Transition, Aalborg University, A. C. Meyers Vænge 15, 2450 Copenhagen, Denmark; monian@plan.aau.dk
* Correspondence: kirsten@outofoffice.cc (K.v.D.); lsi@create.aau.dk (L.S.); Tel.: +45-9940-7633 (L.S.)

Received: 23 October 2020; Accepted: 5 December 2020; Published: 9 December 2020

Abstract: In the past decades, industrial design practice and research have focused extensively on how to optimize production and consumption, as a way to prevent negative environmental impacts, such as resource depletion, pollution, and excessive waste. Recently, the "circular economy" concept is increasingly used to achieve environmental benefits and economic growth simultaneously. Industrial design can contribute to a circular economy by fostering systems changes to achieve durability, optimal reuse, refurbishment, remanufacturing, and recycling of products and materials. Indeed, researchers have examined both the theoretical and practical aspects of how design knowledge can support the transition to a circular economy. However, this body of knowledge has not been systematically analyzed yet. To address this critical gap, this paper poses the following question: *How has industrial design research so far contributed to advancing the circular economy knowledge?* Accordingly, we survey relevant design literature focusing on the circular economy, through a review of contributions published in 42 scientific journals. Based on our results, we discuss how industrial design practices can potentially contribute to a circular economy across four thematic areas: (1) design for circular production processes, (2) design for circular consumption, (3) design to support policy towards the circular economy, and (4) design education for the circular economy.

Keywords: circular economy; circular design; sustainable design; design research; literature review; design education; policy support; industrial design

1. Introduction

Planet Earth cannot sustain the current ways of human development. The negative side-effects of human activity include climate change, destruction of natural ecosystems, and depletion of critical resources on a global scale, jeopardizing the survival of our species [1]. The concept of sustainable development is inextricably intertwined with the idea of staying within limits. In turn, this entails slowing down our growth rate, which seems to be in striking contrast with the dominant economic logic [2,3]. In this regard, the concept of the circular economy has recently emerged as a new paradigm for creating the basis for a sustainable society.

The origins of the circular economy ideas are rooted in earlier engineering views about resource efficiency and product life extension [4], as well as other strategies, including bioeconomy and its

focus on deriving industrial inputs (e.g., materials, chemicals, and energy) from renewable biological sources [5,6]. The circular economy paradigm was nonetheless catalyzed by the Ellen MacArthur Foundation and the European Commission within business and policymaking [7–9]. From a theoretical standpoint, the circular economy is defined as " ... a regenerative system in which resource input and waste, emission, and energy leakage are minimized by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling" [10]. The circular economy promises to couple economic growth and environmental benefits by increasing the efficiency of industrial activities [11]. Therefore, the circular economy is perceived by businesses as a positive opportunity, instead of a limitation, for transitioning towards a different development model [12,13]. As a result, its principles are becoming some of the prominent guidelines for the design of industrial products and processes, but also for the creation of new business models [14] and innovation ecosystems based on the collaboration of multiple stakeholders [15,16]. However, it is also important to keep a critical perspective, since the ambition of achieving economic growth and limiting environmental impact simultaneously may be based on unrealistic techno-optimism [17]. Relatedly, the circular economy might help to lay the foundation for renewed growth-driven economic strategies [18], but it might also sustain the current dominant neoliberal political and economic ideas that represent one of the root causes of negative societal and environmental impacts [2,19].

Design is fundamental to support the transition to a circular economy [20]. In the context of this paper, with the word "design" we do not refer to the aesthetic and functional qualities associated to a product, but rather to a creative, rational, and iterative innovation process to create solutions to complex problems [21] and ultimately turn "existing situations into preferred ones" [22]. Over five decades of literature in the field of design clarify that this process can be applied at different levels, ranging from the creation of graphics and symbols to the creation of material artifacts, intangible services, and, more broadly, even complex systems such as entire cities [23,24]. Within the wider field of design, industrial design is broadly understood as a discipline focusing on product and service development [25]. As such, industrial design is indeed a process to solve complex problems [26], and sustainable development can only be achieved by solving a multitude of interrelated complex problems [27]. Thus, the connection between these two concepts is straightforward [28,29]. Accordingly, academic research has produced an extensive body of knowledge on the subject, which may be labelled with the term "design for sustainability" [19]. Seminal ideas on design for sustainability may be traced back to decades ago and found in the work of Buckminster Fuller and Victor Papanek [30,31]. As explained in recent literature reviews, these ideas consolidated and evolved over time into several streams [19,32] including ecodesign [33,34], product service system design [35,36], sustainable business model design [37,38], and transition design [39]. Recent reviews have mapped these streams and the evolution of design for sustainability [19]. More recently, "circular design" has been emerging as a new frontier of sustainable design research [32,40]. There have been several recent studies that explored various topics at the intersection between design and the circular economy. For example, Tukker et al. [20] investigated the ways in which the concept of product service system design evolved in relation to the circular economy. Lofthouse and Prendeville [41] analyzed the positioning of human-centered design within the circular economy by bringing together insights from various fields including economics, sociology, management, and ecology. Baldassarre and colleagues [42] discussed how design can be applied on a strategic level for the creation of eco-industrial clusters, which represent a physical manifestation of the circular economy.

Despite this growing interest, the majority of these studies have approached circular design from a variety of perspectives and published in multidisciplinary outlets such as *Journal of Cleaner Production* (e.g., [10,43]), *Sustainability*, (e.g., [44]), and *Journal of Industrial Ecology* (e.g., [12]). In journals that are more specifically centered on industrial design research [25], the circular economy has not been studied extensively and in connection to other disciplines. As such, the full potential of how design can contribute to and advance the circular economy is far from released. While some scholars

have provided an analysis of different streams of research within the broader rubric of design for sustainability [19], specific streams—such as the role of industrial design for the circular economy—have not been subjected to close scrutiny. As already explained, the concept of circular economy is based on earlier engineering-related ideas [45], and design literature has already discussed some of these ideas (e.g., [46]). However, the areas in which industrial design can advance the current body of literature explicitly labeled as circular economy knowledge remain still underdefined. The aim of this paper is to address these issues—and the gap they represent within circular design research—by investigating the design field and identifying design practices that can be adopted by practitioners and further studied by design scholars, and consequently that can foster circular economy projects and processes. According to our aim, we pose the following research question:

How has industrial design research so far contributed to advancing the circular economy knowledge?

To address this question, we carried out a systematic literature review of articles published in key industrial design journals identified by Gemser et al. [25] as the most influential outlets in the field. The review identified a number of design practices in four thematic areas, which can potentially contribute to the circular economy from different angles: (1) design for circular production processes, (2) design for circular consumption, (3) design to support policy towards the circular economy, and (4) design education for the circular economy. Addressing the research question above specified also gave us the opportunity to shed light on where future industrial design research for the circular economy might and should move forward.

The remainder of the article is organized as follows. Section 2 presents the methodology we adopted for reviewing and synthesizing prior studies. We then present the results of the review in Section 3. In Section 4, we discuss our results as potential avenues for future research.

2. Methods

Our review examined articles published in 42 key industrial design journals. The selection of journals stemmed from a study that identified 40 journals as particularly relevant for industrial design research; the study was based on an online survey for design scholars that assessed journals in terms of two quality metrics: popularity and indexed average rank position [25]. To this list, we added two recent journals (*She Ji* and *Design Science*), which were launched after Gemser et al.'s article was published, are indexed in Scopus, publish in English language, and have design as their core focus. The final list of journals included in our review (Figure 1) is also consistent with other previous reports based on surveys among design scholars [47].

List of journals included in the review

1. Applied Ergonomics
2. Creativity and Innovation Management
3. CoDesign
4. Computer-Aided Design
5. Design and Culture
6. Design Issues
7. Design Management Journal
8. Design Philosophy Papers
9. Design Research Quarterly
10. Design Science
11. Design Studies
12. Digital Creativity
13. Ergonomics
14. Ergonomics in Design
15. Empirical Studies of the Arts
16. Human-Computer Interaction
17. Human Factors
18. Information Design Journal
19. Interacting with Computers
20. International Journal of Art & Design Education
21. International Journal of Design
22. International Journal of Product Development
23. International Journal of Sustainable Design
24. International Journal of Technology and Design Education
25. International Journal on Interactive Design and Manufacturing
26. Journal of Design History
27. Journal of Design Research
28. Journal of Engineering Design
29. Journal of Interior Design
30. Journal of Material Culture
31. Journal of Mechanical Design
32. Journal of Product Innovation Management
33. Journal on Multimodal User Interfaces
34. Materials & Design
35. Personal and Ubiquitous Computing
36. Research in Engineering Design
37. She Ji
38. The Design Journal
39. The Journal of Sustainable Product Design
40. The Senses & Society
41. Visible Language
42. Visual Communication

Figure 1. Journals included in the review.

The journals included in this review were searched for the term "circular economy" (in all the text of the articles) using both Scopus and Google Scholar. We considered articles published in each journal until January 2020. Figure 2 presents our process of searching and locating relevant articles included in this review. To ensure methodological rigor and quality, we followed the guidelines of the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) protocol, which was developed by an international network of collaborators within the healthcare field. It proposed an evidence-based set of items to report in systematic reviews and meta-analyses [48,49]. In our case, the PRISMA protocol was articulated into three steps: (1) identification and screening of all relevant articles, (2) eligibility assessment, and (3) decision for inclusion/exclusion.

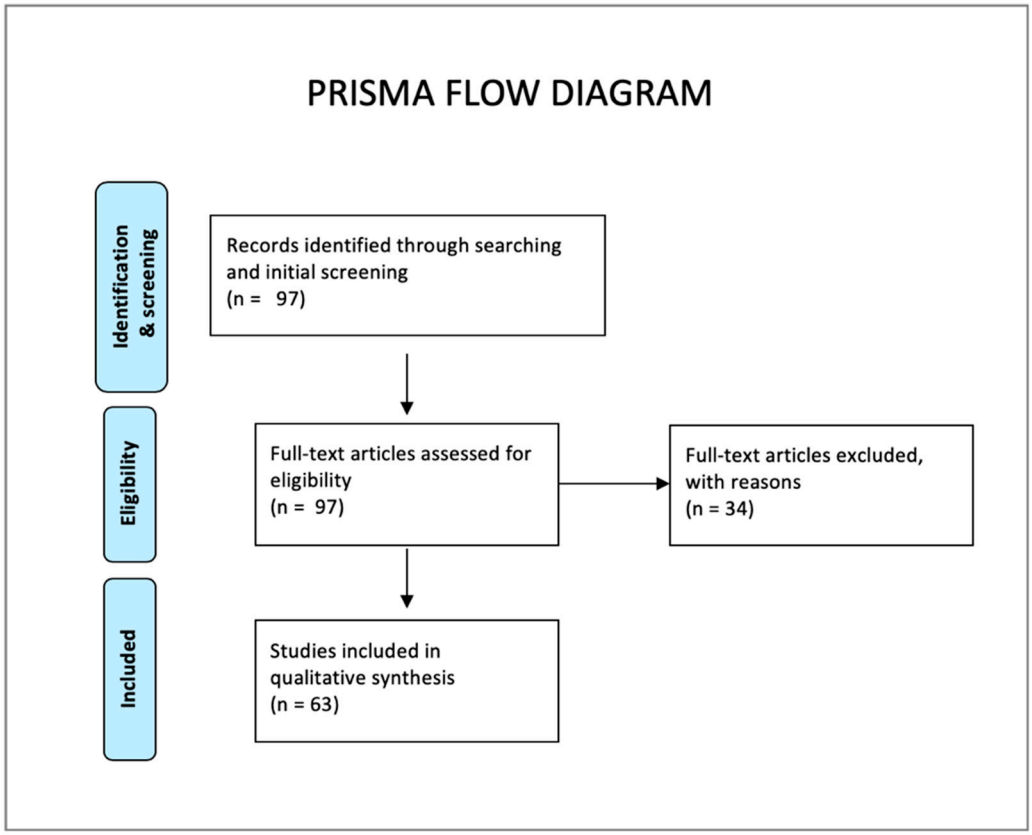

Figure 2. PRISMA flow diagram, which reports the number of articles examined through the chosen systematic review protocol.

We initially identified 97 articles, which were screened to check whether the term "circular economy" was included (identification and screening phase). The initial search returned also articles that were marginally connected to the circular economy (i.e., the term only appeared in the reference list or was used in a sentence for which the circular economy was not a central theme). To filter out these articles, two of the authors scanned the full text of all the articles retrieved (eligibility assessment phase) and decided to exclude 34 of them, resulting in a final sample of 63 articles. These articles were independently examined by two of the authors of this review, who produced a table in which the bibliographic data and the core content of each article were reported and summarized. We enclose as an appendix a file containing bibliographic information of the articles reviewed.

To cluster articles exploring similar topics, we proceeded according to two intertwined processes: (1) the authors categorized the articles identifying key topics for each article and grouping the articles in relation to similarities in topics (following processes described in [50,51]); and (2) the authors continuously readjusted the categorization in relation to broad and core ideas elaborated in key literature and reports on circular economy [10,43,52]. We used these ideas to support an inductive

approach for the analysis of qualitative data [53], commonly used in literature reviews to interpret concepts and identify emergent themes [54]. Since there are no previous systematic reviews on how industrial design research treats the concept of circular economy, we found an inductive approach particularly suited to make sense of a still fragmented knowledge [55]. The categorization process followed these steps [56,57]: (a) open coding phase: two of the authors read the full text of each article in parallel and assigned some preliminary freely generated labels to each article; (b) grouping: the two authors grouped the labels under higher-order headings; (c) categorization: all the authors readjusted the headings and elaborated the final categories also taking into consideration other integrative scholarly work [10,43] and other reports [7–9,52] on circular economy. Based on this process, our review identified four major thematic areas: (1) design for circular production processes, (2) design for circular consumption, (3) design to support policy towards the circular economy, and (4) design education for the circular economy. In the following sections, we discuss these practices and the role of design for each theme.

The review also showed a substantial increase over time in the number of articles exploring circular economy in industrial design journals (see Figure 3). The journals that published the highest number of articles are *The Design Journal* (34 articles), *Materials and Design* (7 articles), and *She Ji* (3 articles).

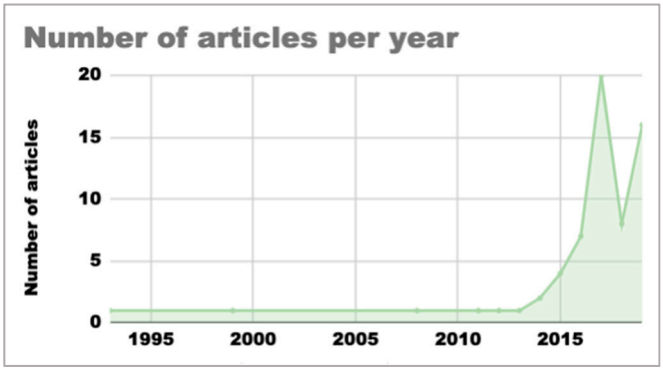

Figure 3. Diagram showing the publication date of the 63 articles included in our review.

3. Results of the Thematic Analysis

3.1. Design for Circular Production Processes

Scholarly contributions pointed out that the development of products, institutions, and systems to recycle, remanufacture, and reuse is one of the key themes for design innovation [58] and design-driven manufacturing processes [59]. In our sample, we have identified a good number of articles (37) that refer to the role of design for innovating and optimizing the production and manufacturing processes with a focus on the circular economy. These articles revolve around three main design practices: distributed manufacturing, open design, and design for value recovery.

As for distributed manufacturing, there is an increasing scholarly interest, especially in relation to the makers movement, fab labs, additive manufacturing, and digital fabrication. Distributed manufacturing can be conceptualized as a network of small-scale manufacturing units that facilitates localized production in community-based workshops [60]. It is seen as a promising production model that supports the circular economy by shortening supply chains and reducing transportation impacts through localized manufacturing, thus achieving an environmental impact reduction throughout the product's lifecycle—which is also a key tenet of eco-design [61]. In our sample, Mullagh et al. [62] studied small and micro maker enterprises in Cumbria (UK), which use wool as their main material. Their findings suggest that holistic design approaches appear to enable enterprises to source sustainable and ethical materials, to design sensitive to place, and to consider waste and longevity of products. Markou et al. [61] examined the environmental implications of additive manufacturing in early design phases. Their findings suggest that there are a number of meta-requirements

that should be taken into account to support environmental decisions within multidisciplinary design teams during creativity sessions. These include (1) enabling environmental experts to share their knowledge, (2) identifying the inputs and outputs of activities (e.g., additive manufacturing), (3) integrating environmental considerations through process tasks, timelines, and information exchanges, and (4) integrating additive manufacturing and lifecycle considerations into the early design activities. A few authors provided a more critical and in-depth overview of the possible limitations of the maker-based distributed production models and their environmental value and impact [63]. In particular, even though such approaches might play an important role in involving a range of stakeholders in circular design practices, they do not necessarily lead to the creation of products with longer lifespans or diminish production and consumption by replacing mass production [63]. Although the makerspaces and fab labs with strong ecology-oriented visions and programs can provide important role models, the consequences of personal fabrication approaches "often seem to be invisible in Fab Labs in the global North: the reality of the supply chains outside the Labs, the reality of electronic component manufacturing and the toxic reality of e-waste" [63]. Fab Labs and similar spaces must adhere to guidelines and replicable processes that facilitate a more sustainable approach to co-creation [64]. Others noted how "there is a visible risk that the innovative momentum of 'making' gets lost in response to market pressures, lacking awareness of customers and makers not yet able to capitalize on their collective powers, missing the chance of innovating their own ways of collaborating in interdisciplinary teams" [65]. This, in turn, might limit the impact of the maker movement on circular design practices.

The second core area of focus is open design, which is a topic partly related to and often discussed in the context of distributed manufacturing. Open design is a practice in which publicly shared design information enables collaboration and local production, such as in the case of the makerspaces [63]. Several papers have provided a critical review of the steps towards the implementation of open design practices for the circular economy. Some of these studies have been conducted within the textile industry and pointed to the need to more openly share knowledge, skills, resources, and experiences so as to fully re-evaluate the ethical aspects of textile production [66–69] and support circular design approaches [61,70]. To this end, Smith [71] explored the barriers and opportunities associated with localized manufacturing in the context of rural maker centers in Scotland. The author suggests that local manufacturing can shorten supply chains for certain products and respond to the local needs quickly in remote regions. This can be achieved by a dispersed but connected network of different types of maker centers at domestic, industry, community, and regional levels, which can address the needs of citizens, businesses, and industry and scale up innovations from the local level. Moorhouse and Moorhouse [72] explored a number of initiatives by large multinational companies, smaller niche brands, or more experimental educational projects to implement open design practices aimed at zero waste fashion. An example for such practices is *Re.Verso*, a business collaboration among three Italian textile mills, which enables manufacturers to process their surplus waste through an innovative supply chain system. Fashion brands and retailers can use the "open door" platform to transform their textile waste into high-quality fibers and eventually knitted and woven fabrics for fashion. Another case study in the fashion industry looks at the diversity of roles, values, skills, and methods that fashion activists can adopt and at some of the challenges and opportunities for designers and researchers interested in transforming the fashion system towards sustainability [73]. Scholarly works that look at other industry sectors are sparser. Gallagher et al. assessed a conservation charity and their management approach, which combines open and design-driven approaches to support renewable energy projects [74]. They suggest that a design-driven approach can enable firms to understand, anticipate, propose, and influence new product meanings and languages, and enact its stakeholder network to contribute to a low-carbon community. Similarly, Morel et al. [75] presented the case of an automotive company and how it leverages its eco-innovation community via the creation of a common culture, original structures, and collaborative practices. Two processes play a prominent role in this approach: (1) a collaborative lifecycle framework, which enables

community to explore, engage, elucidate, and evaluate the innovation in development, and (2) a landing process that guarantees its successful implementation. Watson and colleagues mainly focused on the capabilities needed to foster multistakeholder collaboration in environmental innovation, including circular models: specific operational capabilities (e.g., scientific expertise, design, manufacturing, technological, and marketing capabilities); first-order dynamic capabilities to manage the engagement; and second-order dynamic capabilities "to make use of contrasting ways of seeing the world to reframe problems, combine competencies in new ways, and co-create innovative solutions (value framing), and to learn from stakeholder engagement activities (systematized learning)" [76]. Others use inspiration from "systemic design" to foster strategies and approaches for the circular economy [77], develop tools and methods for sustainability-oriented decision-making [78], and facilitate collaboration in challenges related to the circular economy, which are of a connected nature by default [79].

Lastly, design scholars studied the concept of design for value recovery, which looks at ways in which design can work with materials to retain and make better use of their value. Several papers looked at design methods to facilitate value recovery [80]. Mont [81] focused on product durability and researched various design methods to lengthen the product lifespan (e.g., design that can be upgraded or reused, easily maintained, replaced; design for remanufacturing; design for upgrading; mass-customization; timeless design) and strategies that can maximize the utilization rate of consumer durables (e.g., shift from consumer ownership to producer ownership; shift from supply chain to value chain actor-networks). Haug [82] described "resilient design" with a fine-grained classification of both causes of product replacement and organizing means to extend the longevity of products. Cong et al. [80] suggested a method to improve end-of-use product recyclability through a sequence of steps that evaluate various end-of-use scenarios and then analytically define which components of a product are more suitable to be disassembled, recycled, and reused. Goldsworthy [83] proposed to take into account the multiple rhythms and speeds (e.g., slow and fast fashion speed) within a product's entire lifecycle in order to design effective circular fashion products. For example, extending the lifetime of a "fast product" might not necessarily be more sustainable if it comes at the cost of recyclability, or if durability is achieved through material features that require care and laundry with higher environmental impacts. By visualizing the speed of a product in different stages of its lifecycle, designers can become aware of the notions of "speed". This can allow them to consider and engineer multiple and proportionate speeds on the basis of products' environmental impacts in different stages of their lifecycle and, in turn, support them in more effectively retaining the value of materials. Lastly, some scholars examined the characteristics of construction materials in light of circular production models or the use of waste as a core development material [22,68,69,84–92]. For instance, Turrini explored the tradition of creating objects and furniture out of cardboard as a manner in which short and circular production chains can be activated [93]. To activate such circular production processes, designers will have to learn how to manage complex, large-scale, and cross-disciplinary processes and an increasing high number of virtual work platforms and extensive human–machine and human–system interactions, and consequently, a significant input from the fields of ergonomics and human factors is expected [94].

3.2. Design for Circular Consumption

Besides circular production, a handful of authors studied what we refer to as circular consumption, and explored how consumer behavior and perception, with a focus on the different phases of consumption from purchasing to use and maintenance, can support the implementation of the circular economy. Bhamra et al. [95] highlighted the role of routines and rituals in using, maintaining, repairing, disposing, and recycling products. They suggest that a lack of awareness, information, and concern, as well as being locked in certain lifestyles are barriers that need to be overcome and taken into account when designing interventions and products to change consumer behavior. Ackermann [96] explored the motivational aspects of repair and maintenance behavior. The author argued that a focus only on design of products for ease of repair and maintenance is not enough; consumers should also feel

motivated to care for their products. Two factors that play an essential role in influencing consumer behavior are consumers' motivation and their ability to repair and maintain. Besides these two factors, triggers related to, for example, appearance, time, or previous care experiences are needed to enact consumers to care for their products. Similarly, numerous authors examined how a closer understanding of the attitudes and perspectives of end-users as it pertains to ownership, disposal, and reuse of objects, and the key mechanisms behind caring for one's possessions (e.g., affection, responsibility, and commitment) can greatly help extend the lifespan of products [66,67,69,97]. While assessing six German hospitals and their recycling performances, Vogt and Nunes [98] analyzed some motivational factors for environmental behavior. Their study pointed out how methods to make efficient waste handling at work easier (e.g., communication design oriented towards providing information and feedback to staff, clear labelling design, and re-organizing the physical layout of spaces so as to host several waste bins) are viewed as probable success factors that can lead to more sustainable staff behavior.

Other authors focused on educational and communicational aspects. Fassio [99] developed an online intervention, in the form of a website, which aimed at providing fine-grained information on food supply chains and stimulating sustainable behavior. The website provides gaming opportunities where end-users can play the role of an entrepreneur and make choices regarding the supply chain (e.g., what kind of irrigation system to implement for their farm or what kind of ingredients to use when producing jam). Every single choice can potentially affect the sustainability and circularity of the final product distributed to the market. The idea is to educate the players and make them aware of the importance of purchasing food that has been produced through processes grounded into the circular economy. Mugge et al. [100] studied consumers' acceptance of refurbished products as an alternative to purchasing new ones. Their findings suggest that especially visual information (i.e., signs of wear and tear) about prior use negatively impacts consumers' evaluations of refurbished electronics. This has implications for designers in choosing different refurbishment options and increasing the likelihood of customers' acceptance of refurbished products. Vanhamäki et al. [101] sought opportunities to use "information design" to promote environmental awareness, produce more understandable information about renewable energy possibilities, and stimulate consumers to make investments in renewable energy solutions. Visualizing complex data in the form of story-based visualizations, such as animations, appears to better accommodate the information needs of rural actors in comparison with posters or other graphical visualizations.

3.3. Design to Support Policy towards the Circular Economy

Another group of authors researched the support that design can offer to public administrations when creating policy actions, legislation, and other measures that implement the circular economy.

Some authors looked at how, in such contexts of intervention, design processes can significantly support participation and inclusion of citizens and other stakeholders. Munthe-Kaas and Hoffmann [102], for example, looked at "compositionist design" as a way to create "things" (i.e., collectives of humans and non-humans, which can be sustained and nurtured by design action), and at how it can support public participation and inclusion of citizens when planning the future of our cities. Their findings support the idea that a design approach can foster more inclusive governance processes. Reitsma et al. [103] studied how climate fiction stories can be used as a prompt to engage different societal stakeholders and experts in debates around moral, ethical, and societal issues in the transition towards a low-emission society. The authors suggest how these stories can potentially "be extended as a tool to back-cast societal change and policy making" [103].

A lack of theoretical accuracy around the concept of the circular economy could not only prevent designers from coming up with effective solutions but also prevent policymakers from developing concrete actions and policies to support and promote the uptake of the circular economy. Indeed, the lack of clear definitions of the concept of the circular economy prevents the root problems of economics on growth being solved [104]. The need to provide such theoretical accuracy prompted several authors

in presenting theoretical considerations to position the concept of the circular economy in relation to other design for sustainability approaches [19,41]. Ceschin and Gaziulusoy [19] highlighted how various design for sustainability approaches (e.g., cradle-to-cradle design, biomimicry, eco-design, systemic design, product-service system design, and design for transitions) are critical in implementing circular economy solutions; the article also reviews a number of articles and projects that point toward potential policy and innovation pathways. Lofthouse and Prendeville [41] analyzed the positioning of design within current circular economy studies, noting how they tend to reflect a "dominant positivist paradigm that leads to the treatment of users as passive subjects of innovation" [41], rather than considering how design can foster more participatory innovation processes. These papers complement previous detailed and historiographical assessment on design and its environment in all its definitions [105]. The intention of these studies is to offer a more accurate view of concepts and theories connected to the circular economy, thus providing fine-grained analytical and interpretive instruments to those institutions and policymakers that need to support the development and uptake of the circular economy in society.

Some other authors examined specific government and policy measures that could support the circular economy. Cooper [106] studied how some key components of broad economic infrastructures—such as the potential of fiscal reform to alter the costs of manufacturing and after-sales services, the environmental objections to industrial concentration and free trade, and the manner in which economic progress is measured—can foster sustainable product design and maximize products designed with minimal environmental impact. Thackara [107] focused on the (re)connection between urban and rural systems using "bio-regions" and proposed a "circular bioregional framework" and new shared metrics for measuring value: "If health of place is to replace money as a shared value metric, we will have to describe and measure 'health' with greater precision than we do now" [107]. Lastly, he put forward ideas on enabling conditions for system change, such as the reconnection of urban and rural and place-specific social infrastructures. Barbero and Bicocca [108] described an Italian circular economy project oriented toward cultivating design-driven and collaborative engagement of universities and political commitment of local authorities, government offices, associations, and public bodies to join forces and create a more systemic view and a broader approach in territorial development. Battistoni and Barbero [109] argued that there is an opportunity for systemic design to support the development of eco-entrepreneurship incubators, which can boost local circular economies by training and offering advice to local companies and other organizations and by helping them operate in a more sustainable way. The authors provide some indications for policymakers to support such incubators: (a) offering economic support and tax breaks to help companies transition to more sustainable manufacturing technologies and biofuels, (b) involving such actors in more collaborative policy design processes, and (c) enhancing the creation of a sharing economy through fewer legislative barriers.

3.4. Design Education for the Circular Economy

A variety of scholars shared ideas on how the circular economy is taught in design schools.

Many authors converge on the need to modify and broaden the current curricula of design schools to include key circular economy approaches and related processes for product design, co-creation, management, and marketing [110]. To this end, design education should more closely embrace experimental approaches in open design and distributed production paradigms, which can support the uptake of circular economy practices [111]. By focusing on open design and distributed production experiments and inviting others to participate in those experiments as a form of co-creation, a new cohort of future designers will be educated so as to be better prepared to contribute to a future circular economy. Virtanen et al. [112] assessed a *Circular Material Library* (i.e., a library containing a selection of available recycled materials) to understand how it can impact circular re-thinking and re-designing of products. They found that such tools can help to develop circular economy competencies in designers and companies, particularly with regards to using recycled materials to replace virgin ones and creating collaborative networks through symbiosis products that are made of recycled and other materials.

Past and current experiences of education programs that clearly oriented their activities toward taking into consideration the circular economy can provide insights on how to reshape curricula of design schools. Earley [113] chronicled the last two decades of the Textiles Environment Design research group at the University of the Arts London and revealed the effect circular design had on different projects at the intersection of educational, research, and practice-oriented activities.

Several other papers discuss in detail the particular skill sets that designers need in order to address complex challenges behind the circular economy, in particular collaboration, facilitation, and negotiation skills [114,115]. These skill sets can support lifecycle thinking, which has now become "a fundamental principle for developing new designs and managing their life scenarios appropriately in contributing to a circular economy" [114]. Haemmerle et al. [116] argued that current design education does not teach the practical expert knowledge needed to operate in the field of sustainability. In order to address this gap, Mestre and Cooper introduced a conceptual framework in which technical cycles—that is, "technical and/or technological use and transformation of material and energy resources, and their design optimization to the highest possible levels of efficiency" [117]—and biological cycles—that is, "the biological design solutions occurring in (or inspired) by the natural ecosystems, in which materials are cycled in nature over time" [117]—are leveraged to frame circular economy design interventions. Such a framework could be used "to initiate a discussion about the role of design in higher education" [117]. By analyzing a research project aimed at studying how textile waste can be recycled through more sustainable chemical processes, Earley showed that it was vital for the designers and the design researchers in the project to develop communication skills to build bridges between the different partners involved [118].

4. Discussion and Conclusions

4.1. Contribution of Industrial Design Research to Circular Economy: Thematic Areas

This paper, by means of a systematic literature review, uncovers how industrial design research has played a role in advancing the circular economy. In particular, we identified four thematic areas, which are relevant to show where the focus of industrial design research has been placed so far, and to foster a debate on what design research may focus on in the future. Figure 4 presents a visual summary of the main categories that emerged from our study, which are well aligned with the key themes that are stressed in seminal reports related to circular economy [7–9,52]. We summarize our findings in Section 4.1. Then, in Section 4.2, we discuss how design research can inform future design and interdisciplinary research on the circular economy.

Several contributions explored how design can optimize the production processes to support the circular economy. This focus is by far the biggest thematic area, with a highlight on three main design practices: distributed manufacturing, open design, and design for value recovery. A majority of studies show how design can contribute to the circular economy by understanding diverse stakeholders (i.e., users, experts, businesses, and local actors) (e.g., [63–65]), imagining desired future states of production (e.g., [60,71]), applying holistic approaches (e.g., [77]), proposing various business processes (e.g., [74,75]), as well as creating new product meanings and languages (e.g., [68,69]). Most scholars describe case studies around these practices and propose frameworks, approaches, and tools. This is natural as design scholars often conduct research that employs methods, practices, and processes of design practice in generating knowledge [119]. In many cases, these studies present actionable information and content that can be of interest for practitioners (e.g., detailed descriptions of the application of design tools, methods, and frameworks in specific contexts related to the circular economy). As also illustrated in the report *Towards the Circular Economy* of the Ellen MacArthur Foundation, effective design approaches are needed to support businesses and circular processes [52]. In this regard, industrial design research can contribute to the circular economy by building on design knowledge to create design interventions and related methodological approaches and tools that can address contextual needs.

Figure 4. Thematic areas that emerged from the literature review.

Other scholars focused on design for circular consumption, exploring how design could influence pro-environmental consumption behavior. Contributions mostly circle around two aspects. First, it is critical to have a clear understanding of consumers' routines, rituals, and motivational aspects of using, maintaining, repairing, disposing, and recycling products (e.g., [95]); such understanding can help in the design of longer-lasting products and support the implementation of the circular economy (e.g., [67,97]). Second, visual and communication design—for example, applied to flyers, product labels, and websites that present key characteristics of products and services and the way in which they leverage circular economy processes—can greatly help to educate consumers (e.g., [99,100]). The relevance of empowering consumers for sustainable consumption is also underpinned by the literature review of Camacho-Otero et al. [44], as well as in the new *Circular Action Plan* of the European Commission [8]. A new generation of ethical consumers is pushing companies to rethink their purpose and business models. According to a trend report released by the global design and innovation consultancy Fjord, "organizations will need to redesign their systems and business models to fit the "circular economy", where consumers are active participants, and sustainability is built into their products and services" [120]. The need to develop new business models and consumption patterns is also confirmed by academic literature outside design research, for example, by scholars who have been working on circular business model design [121,122].

Our review also shows that there are some 10 contributions regarding how design can support circular economy policies. Some of the reviewed papers provide actionable advice that mostly revolves around two aspects: (1) how design processes and methods can support the engagement of citizens and other stakeholders in a more collaborative policy making (e.g., [102]), (2) how policymakers can support the circular economy (e.g., by providing economic support and tax breaks to help companies transition towards manufacturing pipelines and distribution systems that are more grounded into the circular economy) (e.g., [108]). Other contributions are more theoretical in nature and only indirectly support policy making by specifying the distinction between various and adjacent design for sustainability approaches (e.g., cradle-to-cradle design, biomimicry, eco-design, systemic design, product-service system design, and design for transitions) [19] or by clarifying the potential of a human-centered design approach while working on circular economy projects [41]. This granular view of design can help government agencies and policymakers understand the potential of design and how it can be supported within broader policies for the circular economy [123].

Finally, the last category that emerged from our review groups papers that study how design education relates to the circular economy. Some of these papers analyze current curricula of design schools and note how these curricula should be modified so as to include key circular economy approaches (e.g., [110,111]). While at school, design students should be exposed to and possibly experiment with approaches such as open design or distributed production paradigms and get familiar with processes that can promote the circular economy. Some other papers look at the skill sets that designers need to have to effectively support circular economy projects, such as collaboration, facilitation, and negotiation skills, which allow designers to better work together with experts in circular business, production, and distribution models and lifecycle thinking (e.g., [114–116]). Building capacity for the circular economy and design starts by investing in education. According to the report *Towards the Circular Economy* from the Ellen MacArthur Foundation, "strengthening the education of future generations of entrepreneurs, designers, chemical and industrial engineers, of procurement officers, and product managers, will be critical to completely rethink and overturn today's linear world" [52].

A few more reflections emerge from a comparative analysis of the 63 papers included in our research. Over time, design studies concerned with the circular economy have started to adopt a wider perspective, which conceptualizes design interventions as components of broad socio-technical systems. This perspective oriented towards systems thinking has emerged more strongly in recent studies (e.g., [107,108]), where the authors tend to focus on the organizational, structural, systemic, and economic levels of the design process. In terms of scale, it is as though the more recent studies reviewed in our paper operate at a different level of zoom and strive to get a broader view of design as entangled in socio-technical systems. Obviously, for some of the categories we reviewed, for example, *Design to support policy towards the circular economy*, having such wider outlook is critical as studies relating to policy have to take into consideration interplay of multiple societal stakeholders and factors. In other categories (e.g., *Design for circular production processes*), a significant number of studies adopt a closer level of zoom on the material aspects of design by looking at the properties of construction materials. As such, the way in which the concept of the circular economy is approached is not homogeneous across all the categories reviewed in our study.

The publication pattern shown in Figure 3 highlights a substantial increase over time in the number of articles exploring circular economy in industrial design journals. However, not all the categories have developed over time according to the same pattern. In particular, the category of *Design education for the circular economy* has developed quite recently and a bit later than the other categories. This shows that the concept of the circular economy has gained a centrality within the current debates in industrial design research and, as such, it is deemed as a critical theme to revitalize current educational curricula in light of the environmental challenges that our planet is facing. Within these debates, various authors (1) stress the potential of design methods and approaches to foster the engagement and collaboration of the diverse stakeholders needed to operate at scale on circular economy interventions, and, therefore, (2) point to the need of facilitation skills among designers. However, only few authors realize how such multistakeholder collaboration is rooted into power dynamics and that design is inseparable from politics (e.g., [102]). As such, industrial design research should try not to overemphasize the potential of design-driven collaborations and rather try to grasp more accurately the complexity of real-world problems as strictly entangled with dynamics of power and authority.

4.2. Avenues for Future Research

In spite of this significant potential, there are still critical areas and open issues that industrial design research needs to address more thoroughly by also drawing on insights from other disciplines. According to the results of our systematic review, empirical research on how design knowledge and expertise can advance the circular economy is still limited. In particular, the majority of studies propose approaches and tools that are generally only piloted in one particular context. However, there appears to be a need for further understanding, testing, and implementing of these approaches to learn what works and what does not. This is essential to generalize insights, and therefore to increase

the impact of design research for the circular economy. Consequently, as a first point, we suggest that, besides proposing new design tools, methods, and frameworks, design researchers should also carefully assess possibilities and limitations of existing ones. Such assessment should also take into account how existing tools, methods, and frameworks can be applied in different contexts that face similar problems [124,125]. Second, and linked to the first point, we encourage more case studies and interdisciplinary research on the proposed design practices that can foster circular economy projects and processes. Case studies can be used precisely to examine how specific design practices (and, therefore, specific tools, methods, and frameworks) played out in one or (ideally) multiple contexts of interventions. This knowledge could help not only practitioners and scholars but also those education programs that want to embed the circular economy in their curricula. Third, the circular economy requires the involvement of diverse actors (e.g., citizens, businesses, and governments) at domestic, industry, community, and regional levels; creation of new business models, and scaling up innovations [71]. This calls for industrial design research that draws on insights from other disciplines. Fourth, our results highlight that current research tends to focus on some preferred areas of investigation, such as how design can optimize production processes and can influence perceptions and behavior on consumption. Fewer contributions look into how design can contribute to better policies and regulations. Moreover, some industry sectors (e.g., the textile and fashion industry or consumer electronics) and geographic areas (e.g., the UK) are more studied than others (e.g., [60,70–72,97]). Consequently, we encourage future research investigating other sectors and geographic areas, where specific socio-economic, cultural, or industry conditions might affect the way in which design practices and circular economy processes play out.

As a more general consideration, we also note that multidisciplinary research on the circular economy is still emerging [126]. As suggested by Kohronen and colleagues, the "basic assumptions concerning the values, societal structures, cultures, underlying worldviews and the paradigmatic potential of circular economy remain largely unexplored" [127]. Industrial design research can contribute to expanding theoretical considerations on the circular economy, especially if design scholars engage in multi- and trans-disciplinary research that links design to scholarly contributions presented in other fields. To address this issue, industrial design research on the circular economy should not be inward oriented but make links to other disciplines. Knowledge coming from natural sciences, engineering, business studies, and other fields should complement and broaden the perspective of design research.

The need to make links to different research streams is valid within design research as well. In the past decades, communities of design researchers and practitioners clustered around terms such as green design [128], eco-design [129], design for sustainability [130], or transition design [131]. Under each of these rubrics, different bodies of design practices and theories have been developed [19], which overlap in many ways with design research on the circular economy. This fragmentation of knowledge is detrimental because it results in a loss of relevant insights. It is important to link different research streams to consolidate the design knowledge and advance the design field with regards to circularity and sustainability.

Finally, we note that the very concept of the circular economy has been criticized due to its link to the current dominant neoliberal political and economic landscape [19]. With its focus on closing material loops within the current business paradigm, the circular economy can possibly lay the foundations for renewed growth-driven economic strategies rather than counteracting the current pro-growth discourse, which does not acknowledge the social and environmental crises we are facing [18]. As such, the circular economy could be used as a way to decouple economic growth from environmental impact, for example, through "the adoption of cleaner production patterns at company level, an increase of producers and consumers responsibility and awareness, the use of renewable technologies and materials" [43]. A different typology of circularity discourses exists, which classifies circularity visions according to their position on fundamental social, technological,

political, and ecological issues [132]. Industrial design research should more carefully reflect on such critique, and design researchers should more clearly acknowledge such critique.

Author Contributions: Conceptualization, K.v.D. and L.S.; methodology, K.v.D. and L.S.; investigation, K.v.D., L.S., B.B., D.K., M.N. and N.M.; writing—original draft preparation, K.V.D., L.S., B.B., D.K., M.N.; writing—review and editing, K.v.D., L.S., B.B., D.K., M.N. and N.M.; visualization, K.v.D. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Rockström, J.; Steffen, W.; Noone, K.; Persson, Å.; Chapin, F.S.; Lambin, E.F.; Lenton, T.M.; Scheffer, M.; Folke, C.; Schellnhuber, H.J.; et al. A safe operating space for humanity. *Nature* **2009**, *461*, 472–475. [CrossRef] [PubMed]
2. Porter, M.; Kramer, M. Creating shared value. *Harv. Bus. Rev.* **2011**, *17*, 1–2.
3. Schumpeter, J. *The Theory of Economic Development*; Dunker & Humblot: Leipzig, Germany, 1912.
4. Stahel, W. The product life factor. In *An Inquiry into the Nature of Sustainable Societie. The Role of the Private Sector*; Orr, G.S., Ed.; Houston Area Research Center: Houston, TX, USA, 1982; pp. 72–105.
5. Carus, M.; Dammer, L. The Circular Bioeconomy—Concepts, Opportunities, and Limitations. *Ind. Biotechnol.* **2018**, *14*, 83–91. [CrossRef]
6. D'Amato, D.; Droste, N.; Allen, B.; Kettunen, M.; Lähtinen, K.; Korhonen, J.; Leskinen, P.; Matthies, B.D.; Toppinen, A. Green, circular, bio economy: A comparative analysis of sustainability avenues. *J. Clean. Prod.* **2017**, *168*, 716–734. [CrossRef]
7. Ellen MacArthur Foundation. *Towards the Circular Economy: Economic and Business Rationale for an Accelerated Transition*; Ellen MacArthur Foundation: Cowes, UK, 2013.
8. European Commission. *Circular Economy Action Plan. EUGreenDeal*; European Commission: Brussels, Belgium, 2020.
9. European Commission. *Closing the Loop—An EU Action Plan for the Circular Economy*; European Commission: Brussels, Belgium, 2015.
10. Geissdoerfer, M.; Savaget, P.; Bocken, N.M.P.; Hultink, E.J. The Circular Economy—A new sustainability paradigm? *J. Clean. Prod.* **2017**, *143*, 757–768. [CrossRef]
11. Lieder, M.; Rashid, A. Towards circular economy implementation: A comprehensive review in context of manufacturing industry. *J. Clean. Prod.* **2016**, *115*, 36–51. [CrossRef]
12. Bocken, N.; Ritala, P.; Huotari, P. The Circular Economy: Exploring the Introduction of the Concept Among S&P 500 Firms: The Circular Economy: Exploring the Introduction of the Concept among S&P 500 Firms. *J. Ind. Ecol.* **2017**, *21*, 487–490. [CrossRef]
13. Favi, C.; Germani, M.; Gregori, F.; Mandolini, M.; Marconi, M.; Marilungo, E.; Papetti, A.; Rossi, M. Environmental sustainability awareness in product design practices: A survey of italian companies. In Proceedings of the 11th International Conference on Micro- and Nanosystems, Tokyo, Japan, 16–18 August 2006; American Society of Mechanical Engineers: Cleveland, OH, USA, 2017; Volume 4.
14. Bocken, N.; de Pauw, I.; Bakker, C.; van der Grinten, B. Product design and business model strategies for a circular economy. *J. Ind. Prod. Eng.* **2016**, *33*, 308–320. [CrossRef]
15. Den Ouden, E. *Innovation Design: Creating Value for People, Organizations and Society*; Springer: London, UK, 2012; ISBN 978-1-4471-2267-8.
16. Konietzko, J.; Bocken, N.; Hultink, E.J. Circular ecosystem innovation: An initial set of principles. *J. Clean. Prod.* **2020**, *253*, 119942. [CrossRef]
17. Allwood, J.M. Unrealistic techno-optimism is holding back progress on resource efficiency. *Nat. Mater.* **2018**, *17*, 1050–1051. [CrossRef]
18. Valenzuela, F.; Böhm, S. Against wasted politics: A critique of the circular economy. *Ephemera* **2017**, *17*, 23–60.
19. Ceschin, F.; Gaziulusoy, I. Evolution of design for sustainability: From product design to design for system innovations and transitions. *Des. Stud.* **2016**, *47*, 118–163. [CrossRef]

20. Tukker, A. Product services for a resource-efficient and circular economy—A review. *J. Clean. Prod.* **2015**, *97*, 76–91. [CrossRef]
21. Brown, T. Design Thinking. *Harv. Bus. Rev.* **2008**, *86*, 84.
22. Simon, H. *The Science of Artificial*; The MIT Press: Cambridge, MA, USA, 1982.
23. Buchanan, R. Wicked Problems in Design Thinking. *Des. Issues* **1992**, *8*, 5–21. [CrossRef]
24. Cross, N. Forty years of design research. *Des. Stud.* **2007**, *28*, 1–4. [CrossRef]
25. Gemser, G.; de Bont, C.; Hekkert, P.; Friedman, K. Quality perceptions of design journals: The design scholars' perspective. *Des. Stud.* **2012**, *33*, 4–23. [CrossRef]
26. Farrell, R.; Hooker, C. Design, science and wicked problems. *Des. Stud.* **2013**, *34*, 681–705. [CrossRef]
27. United Nations. *Transforming Our World: The 2030 Agenda for Sustainable Development*; United Nations: New York, NY, USA, 2015.
28. Dobers, P.; Strannegård, L. Sustainability and Design. *Bus. Strategy Environ.* **2005**, *14*, 269–271. [CrossRef]
29. Esslinger, H. Sustainable Design: Beyond the Innovation-Driven Business Model: Sustainable Design. *J. Prod. Innov. Manag.* **2011**, *28*, 401–404. [CrossRef]
30. Fuller, R.B. *Operating Manual for Spaceship Earth*; Simon and Schuster: New York, NY, USA, 1969.
31. Papanek, V. *Design for the Real World*; Bantam Books: Toronto, ON, Canada; New York, NY, USA; London, UK, 1973.
32. Baldassarre, B.; Calabretta, G.; Bocken, N.; Diehl, J.C.; Keskin, D. The evolution of the Strategic role of Designers for Sustainable Development. In Proceedings of the Academy for Design Innovation Management Conference 2019, Londom, UK, 19–21 June 2019. [CrossRef]
33. Brezet, H.; van Hemel, C. *Ecodesign: A Promising Approach to Sustainable Production and Consumption*; United Nations Environment Programme (UNEP): Nairobi, Kenya, 1997.
34. Pigosso, D.C.A.; Rozenfeld, H.; McAloone, T.C. Ecodesign maturity model: A management framework to support ecodesign implementation into manufacturing companies. *J. Clean. Prod.* **2013**, *59*, 160–173. [CrossRef]
35. Manzini, E.; Vezzoli, C. A strategic design approach to develop sustainable product service systems: Examples taken from the 'environmentally friendly innovation' Italian prize. *J. Clean. Prod.* **2003**, *11*, 851–857. [CrossRef]
36. Tukker, A. Eight types of product–service system: Eight ways to sustainability? Experiences from SusProNet. *Bus. Strategy Environ.* **2004**, *13*, 246–260. [CrossRef]
37. Baldassarre, B.; Calabretta, G.; Bocken, N.; Jaskiewicz, T. Bridging sustainable business model innovation and user-driven innovation: A process for sustainable value proposition design. *J. Clean. Prod.* **2017**, *147*, 175–186. [CrossRef]
38. Joyce, A.; Paquin, R.L. The triple layered business model canvas: A tool to design more sustainable business models. *J. Clean. Prod.* **2016**, *135*, 1474–1486. [CrossRef]
39. Gaziulusoy, İ.; Erdoğan Öztekin, E. Design for Sustainability Transitions: Origins, Attitudes and Future Directions. *Sustainability* **2019**, *11*, 3601. [CrossRef]
40. McAloone, T.C.; Pigosso, D.C.A. From ecodesign to sustainable product/service-systems: A journey through research contributions over recent decades. In *Sustainable Manufacturing*; Stark, R., Seliger, G., Bonvoisin, J., Eds.; Sustainable Production, Life Cycle Engineering and Management; Springer: Cham, Switzerland, 2017; pp. 99–111. ISBN 978-3-319-48513-3.
41. Lofthouse, V.; Prendeville, S. Human-Centred Design of Products and Services for the Circular Economy—A Review. *Des. J.* **2018**, *21*, 451–476. [CrossRef]
42. Baldassarre, B.; Schepers, M.; Bocken, N.; Cuppen, E.; Korevaar, G.; Calabretta, G. Industrial Symbiosis: Towards a design process for eco-industrial clusters by integrating Circular Economy and Industrial Ecology perspectives. *J. Clean. Prod.* **2019**, *216*, 446–460. [CrossRef]
43. Ghisellini, P.; Cialani, C.; Ulgiati, S. A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems. *J. Clean. Prod.* **2016**, *114*, 11–32. [CrossRef]
44. Camacho-Otero, J.; Boks, C.; Pettersen, I. Consumption in the Circular Economy: A Literature Review. *Sustainability* **2018**, *10*, 2758. [CrossRef]
45. Bocken, N.M.P.; Olivetti, E.A.; Cullen, J.M.; Potting, J.; Lifset, R. Taking the Circularity to the Next Level: A Special Issue on the Circular Economy. *J. Ind. Ecol.* **2017**, *21*, 476–482. [CrossRef]

46. Braungart, M.; McDonough, W.; Bollinger, A. Cradle-to-cradle design: Creating healthy emissions—A strategy for eco-effective product and system design. *J. Clean. Prod.* **2007**, *15*, 1337–1348. [CrossRef]
47. Friedman, K.; Barron, D.; Ferlazzo, S.; Ivanka, T.; Melles, G.; Yuille, J. Design Research Journal Ranking Study: Preliminary Results. 2008. Available online: http://researchbank.swinburne.edu.au/vital/access/manager/Repository/swin:10413 (accessed on 6 December 2020).
48. Liberati, A.; Altman, D.G.; Tetzlaff, J.; Mulrow, C.; Gøtzsche, P.C.; Ioannidis, J.P.A.; Clarke, M.; Devereaux, P.J.; Kleijnen, J.; Moher, D. The PRISMA Statement for Reporting Systematic Reviews and Meta-Analyses of Studies That Evaluate Health Care Interventions: Explanation and Elaboration. *PLoS Med.* **2009**, *6*, e1000100. [CrossRef] [PubMed]
49. Pati, D.; Lorusso, L.N. How to Write a Systematic Review of the Literature. *HERD Health Environ. Res. Des. J.* **2018**, *11*, 15–30. [CrossRef] [PubMed]
50. Galvan, J.L.; Galvan, M.C. *Writing Literature Reviews: A Guide for Students of the Social and Behavioral Sciences*, 7th ed.; Routledge: Abingdon, UK, 2017.
51. Hart, C. *Doing a Literature Review: Releasing the Research Imagination*, 2nd ed.; SAGE Publications Ltd.: Thousand Oaks, CA, USA, 2018; ISBN 978-1-5264-1921-7.
52. Ellen MacArthur Foundation. *Towards a Circular Economy Vol. 1: Business Rationale for an Accelerated Transition*; Ellen MacArthur Foundation: Cowes, UK, 2015.
53. Thomas, D.R. A General Inductive Approach for Analyzing Qualitative Evaluation Data. *Am. J. Eval.* **2006**, *27*, 237–246. [CrossRef]
54. Roy, V.; Singh, S. Mapping the business focus in sustainable production and consumption literature: Review and research framework. *J. Clean. Prod.* **2017**, *150*, 224–236. [CrossRef]
55. Bryman, A. *Social Research Methods*, 3rd ed.; Oxford University Press: Oxford, UK; New York, NY, USA, 2008; ISBN 978-0-19-920295-9.
56. Dey, I. *Qualitative Data Analysis. A User-Friendly Guide for Social Scientists*; Routledge: London, UK, 1993.
57. Elo, S.; Kyngäs, H. The qualitative content analysis process. *J. Adv. Nurs.* **2008**, *62*, 107–115. [CrossRef]
58. Mortati, M. A Framework for Design Innovation: Present and Future Discussions. *Des. Issues* **2015**, *31*, 4–16. [CrossRef]
59. Roos, G. Design-Based Innovation for Manufacturing Firm Success in High-Cost Operating Environments. *She Ji J. Des. Econ. Innov.* **2016**, *2*, 5–28. [CrossRef]
60. Smith, P.; Baille, J.; McHattie, L.-S. Sustainable Design Futures: An open design vision for the circular economy in fashion and textiles. *Des. J.* **2017**, *20*, S1938–S1947. [CrossRef]
61. Markou, F.; Segonds, F.; Rio, M.; Perry, N. A methodological proposal to link Design with Additive Manufacturing to environmental considerations in the Early Design Stages. *Int. J. Interact. Des. Manuf. (IJIDeM)* **2017**, *11*, 799–812. [CrossRef]
62. Mullagh, L.; Walker, S.; Evans, M. Living Design. The future of sustainable maker enterprises: A case study in Cumbria. *Des. J.* **2019**, *22*, 849–862. [CrossRef]
63. Kohtala, C. Making "Making" Critical: How Sustainability is Constituted in Fab Lab Ideology. *Des. J.* **2017**, *20*, 375–394. [CrossRef]
64. Fleischmann, K.; Hielscher, S.; Merritt, T. Making things in Fab Labs: A case study on sustainability and co-creation. *Digit. Creat.* **2016**, *27*, 113–131. [CrossRef]
65. Unterfrauner, E.; Voigt, C. Makers' ambitions to do socially valuable things. *Des. J.* **2017**, *20*, S3317–S3325. [CrossRef]
66. Baxter, W.L.; Aurisicchio, M.; Childs, P.R.N. Materials, use and contaminated interaction. *Mater. Des.* **2016**, *90*, 1218–1227. [CrossRef]
67. Choi, Y.J.; Stevens, J.; Brass, C. Carative Factors in the Design Development Process: Towards Understanding Owner–Object Detachment and Promoting Object Longevity. *Des. J.* **2018**, *21*, 477–497. [CrossRef]
68. Karell, E.; Niinimäki, K. Addressing the Dialogue between Design, Sorting and Recycling in a Circular Economy. *Des. J.* **2019**, *22*, 997–1013. [CrossRef]
69. Lilley, D.; Smalley, G.; Bridgens, B.; Wilson, G.T.; Balasundaram, K. Cosmetic obsolescence? User perceptions of new and artificially aged materials. *Mater. Des.* **2016**, *101*, 355–365. [CrossRef]
70. Valentine, L.; Ballie, J.; Bletcher, J.; Robertson, S.; Stevenson, F. Design Thinking for Textiles: Let's make it meaningful. *Des. J.* **2017**, *20*, S964–S976. [CrossRef]

71. Smith, P. Digital Maker Networks. Benefits, barriers and opportunities for re-localised UK manufacturing for the future. *Des. J.* **2017**, *20*, S2657–S2666. [CrossRef]
72. Moorhouse, D.; Moorhouse, D. Sustainable Design: Circular Economy in Fashion and Textiles. *Des. J.* **2017**, *20*, S1948–S1959. [CrossRef]
73. Mazzarella, F.; Storey, H.; Williams, D. Counter-narratives towards sustainability in fashion. Scoping an academic discourse on fashion activism through a case study on the centre for sustainable fashion. *Des. J.* **2019**, *22*, 821–833. [CrossRef]
74. Gallagher, J.; Coughlan, P.; Williams, A.P.; McNabola, A. Innovating for low-carbon energy through hydropower: Enabling a conservation charity's transition to a low-carbon community. *Creat. Innov. Manag.* **2018**, *27*, 375–386. [CrossRef]
75. Morel, S.; Unger, L.; Buet, G. Behind-the-scenes of eco-innovation at renault: From collective action to breakthrough concepts. *Int. J. Interact. Des. Manuf.* **2016**, *10*, 251–255. [CrossRef]
76. Watson, R.; Wilson, H.N.; Smart, P.; Macdonald, E.K. Harnessing Difference: A Capability-Based Framework for Stakeholder Engagement in Environmental Innovation: HARNESSING DIFFERENCE. *J. Prod. Innov. Manag.* **2018**, *35*, 254–279. [CrossRef]
77. Nohra, C.G.; Barbero, S. Systemic Design for territorial thinking. Circular urban transitions for post-industrial cities. *Des. J.* **2019**, *22*, 915–929. [CrossRef]
78. Santolaya, J.L.; Lacasa, E.; Biedermann, A.; Muñoz, N. A practical methodology to project the design of more sustainable products in the production stage. *Res. Eng. Des.* **2019**, *30*, 539–558. [CrossRef]
79. Goldsworthy, K.; Ellams, D. Collaborative Circular Design. Incorporating Life Cycle Thinking into an Interdisciplinary Design Process. *Des. J.* **2019**, *22*, 1041–1055. [CrossRef]
80. Cong, L.; Zhao, F.; Sutherland, J.W. A Design Method to Improve End-of-Use Product Value Recovery for Circular Economy. *J. Mech. Des.* **2019**, *141*, 044502–044511. [CrossRef]
81. Mont, O. Innovative approaches to optimising design and use of durable consumer goods. *Int. J. Prod. Dev.* **2008**, *6*, 227. [CrossRef]
82. Haug, A. Defining 'Resilient Design' in the Context of Consumer Products. *Des. J.* **2018**, *21*, 15–36. [CrossRef]
83. Goldsworthy, K. The Speedcycle: A design-led framework for fast and slow circular fashion lifecycles. *Des. J.* **2017**, *20*, S1960–S1970. [CrossRef]
84. Appels, F.V.W.; Camere, S.; Montalti, M.; Karana, E.; Jansen, K.M.B.; Dijksterhuis, J.; Krijgsheld, P.; Wösten, H.A.B. Fabrication factors influencing mechanical, moisture- and water-related properties of mycelium-based composites. *Mater. Des.* **2019**, *161*, 64–71. [CrossRef]
85. Bridgens, B.; Lilley, D.; Zeilig, H.; Searing, C. Skin deep. Perceptions of human and material ageing and opportunities for design. *Des. J.* **2019**, *22*, 2251–2255. [CrossRef]
86. Gujel, A.A.; Bandeira, M.; Giovanela, M.; Carli, L.N.; Brandalise, R.N.; Crespo, J.S. Development of bus body rubber profiles with additives from renewable sources: Part II—Chemical, physical–mechanical and aging characterization of elastomeric compositions. *Mater. Des.* **2014**, *53*, 1119–1123. [CrossRef]
87. Niinimäkia, K. Renewing technology-driven materials research through an experimental co-design approach. *Des. J.* **2019**, *22*, 1775–1785. [CrossRef]
88. Ordoñez, I.; Rexfelt, O. Designing from the dumpster: Experiences of developing products using discards. *Int. J. Sustain. Des.* **2017**, *3*, 61. [CrossRef]
89. Peck, D.; Kandachar, P.; Tempelman, E. Critical materials from a product design perspective. *Mater. Des.* **2015**, *65*, 147–159. [CrossRef]
90. Simões, C.L.; Simoes, R.; Carvalho, J.; Pontes, A.J.; Bernardo, C.A. The quest for a sustainable product: An environmental study of tyre recyclates. *Mater. Des.* **2013**, *52*, 196–206. [CrossRef]
91. Tenhunen, T.-M.; Moslemian, O.; Kammiovirta, K.; Harlin, A.; Kääriäinen, P.; Österberg, M.; Tammelin, T.; Orelma, H. Surface tailoring and design-driven prototyping of fabrics with 3D-printing: An all-cellulose approach. *Mater. Des.* **2018**, *140*, 409–419. [CrossRef]
92. Lerma, B.; Palù, D.D. Natural materials. A family on the move, but where is the last stop? *Des. J.* **2019**, *22*, 1543–1554. [CrossRef]
93. Turrini, D. Democratic Cardboard. Materials and design for a sustainable society. *Des. J.* **2017**, *20*, S1682–S1691. [CrossRef]
94. Siemieniuch, C.E.; Sinclair, M.A.; deC Henshaw, M.J. Global drivers, sustainable manufacturing and systems ergonomics. *Appl. Ergon.* **2015**, *51*, 104–119. [CrossRef] [PubMed]

95. Bhamra, T.; Lilley, D.; Tang, T. Design for Sustainable Behaviour: Using Products to Change Consumer Behaviour. *Des. J.* **2011**, *14*, 427–445. [CrossRef]
96. Ackermann, L. Design for Product Care: Enhancing Consumers' Repair and Maintenance Activities. *Des. J.* **2018**, *21*, 543–551. [CrossRef]
97. James, A.M.; Reitsma, L.; Aftab, M. Bridging the double-gap in circularity. Addressing the intention-behaviour disparity in fashion. *Des. J.* **2019**, *22*, 901–914. [CrossRef]
98. Vogt, J.; Nunes, K.R.A. Recycling behaviour in healthcare: Waste handling at work. *Ergonomics* **2014**, *57*, 525–535. [CrossRef]
99. Fassio, F. Systemic Food Design.it a website that narrates food supply chains from a systemic perspective. *Des. J.* **2017**, *20*, S1355–S1366. [CrossRef]
100. Mugge, R.; de Jong, W.; Person, O.; Hultink, E.J. 'If It Ain't Broke, Don't Explain It': The Influence of Visual and Verbal Information about Prior Use on Consumers' Evaluations of Refurbished Electronics. *Des. J.* **2018**, *21*, 499–520. [CrossRef]
101. Vanhamäki, S.; Heinonen, A.; Manskinen, K.; Kälviäinen, M. Information design as a tool for promoting renewable energy. *Des. J.* **2017**, *20*, S1827–S1835. [CrossRef]
102. Munthe-Kaas, P.; Hoffmann, B. Democratic design experiments in urban planning—Navigational practices and compositionist design. *CoDesign* **2017**, *13*, 287–301. [CrossRef]
103. Reitsma, L.; Wessman, S.; Önnevall, E. 'I Believe in That Version of the Future'. Cli-Fi and Design Fictions as Dialogical Frameworks for Expert Engagements. *Des. J.* **2017**, *20*, S1817–S1826. [CrossRef]
104. Nardi, B. Design in the Age of Climate Change. *She Ji J. Des. Econ. Innov.* **2019**, *5*, 5–14. [CrossRef]
105. Madge, P. Design, Ecology, Technology: A Historiographical Review. *J. Des. Hist.* **1993**, *6*, 149–166. [CrossRef]
106. Cooper, T. Creating an economic infrastructure for sustainable product design. *J. Sustain. Prod. Des.* **1999**, 7–17.
107. Thackara, J. Bioregioning: Pathways to Urban-Rural Reconnection. *She Ji J. Des. Econ. Innov.* **2019**, *5*, 15–28. [CrossRef]
108. Barbero, S.; Bicocca, M. Systemic Design approach in policy-making for sustainable territorial development. *Des. J.* **2017**, *20*, S3496–S3506. [CrossRef]
109. Battistoni, C.; Barbero, S. Systemic Incubator for Local Ecoentrepreneurship to Favour a Sustainable Local Development: Guidelines Definition. *Des. J.* **2019**, *22*, 65–83. [CrossRef]
110. Leube, M.; Walcher, D. Designing for the next (Circular) Economy. An appeal to renew the Curricula of Design Schools. *Des. J.* **2017**, *20*, S492–S501. [CrossRef]
111. Collina, L.; Galluzzo, L.; Maffei, S.; Monna, V. Designing Design Education. An articulated programme of collective open design activities. *Des. J.* **2017**, *20*, S1000–S1013. [CrossRef]
112. Virtanen, M.; Manskinen, K.; Eerola, S. Circular Material Library. An Innovative Tool to Design Circular Economy. *Des. J.* **2017**, *20*, S1611–S1619. [CrossRef]
113. Earley, R. Circular Design Futures. *Des. J.* **2017**, *20*, 421–434. [CrossRef]
114. Papalambros, P.Y. Design Science: Why, What and How. *Des. Sci.* **2015**, *1*, e1. [CrossRef]
115. Vermaas, P. A logical critique of the expert position in design research: Beyond expert justification of design methods and towards empirical validation. *Des. Sci.* **2016**, *2*, e7. [CrossRef]
116. Haemmerle, L.; Shekar, A.; Walker, D. Key concepts of radical innovation for sustainability, with complementary roles for industrial design and engineering. *Int. J. Sustain. Des.* **2012**, *2*, 24–45. [CrossRef]
117. Mestre, A.; Cooper, T. Circular Product Design. A Multiple Loops Life Cycle Design Approach for the Circular Economy. *Des. J.* **2017**, *20*, S1620–S1635. [CrossRef]
118. Earley, R. Building Bridges. Design Researchers Making Podcasts to Support Internal Collaboration in an EU Horizon 2020 Scientific Programme. *Des. J.* **2019**, *22*, 1057–1070. [CrossRef]
119. Zimmerman, J.; Forlizzi, J. Research through design in HCI. In *Ways of Knowing in HCI*; Olson, J.S., Kellogg, W.A., Eds.; Springer: New York, NY, USA, 2014; pp. 167–189. ISBN 978-1-4939-0378-8.
120. Fjord. *Fjord Trends 2019*; Fjord: Toronto, ON, Canada, 2019.
121. Bocken, N.; Schuit, C.S.C.; Kraaijenhagen, C. Experimenting with a circular business model: Lessons from eight cases. *Environ. Innov. Soc. Transit.* **2018**, *28*, 79–95. [CrossRef]
122. Tunn, V.S.C.; Bocken, N.; van den Hende, E.A.; Schoormans, J.P.L. Business models for sustainable consumption in the circular economy: An expert study. *J. Clean. Prod.* **2019**, *212*, 324–333. [CrossRef]

123. Li, C.; Rausell Köster, P. Exploring the Opportunities and Challenges of European Design Policy to Enable Innovation. The Case of Designscapes Project. *Sustainability* **2020**, *12*, 5132. [CrossRef]
124. Baldassarre, B.; Konietzko, J.; Brown, P.; Calabretta, G.; Bocken, N.; Karpen, I.O.; Hultink, E.J. Addressing the design-implementation gap of sustainable business models by prototyping: A tool for planning and executing small-scale pilots. *J. Clean. Prod.* **2020**, *255*, 120295. [CrossRef]
125. Keskin, D.; Romme, G. Mixing oil with water: How to effectively teach design science in management education? *Braz. Adm. Rev.* **2020**, *17*, e190036. [CrossRef]
126. Korhonen, J.; Honkasalo, A.; Seppälä, J. Circular Economy: The Concept and its Limitations. *Ecol. Econ.* **2018**, *143*, 37–46. [CrossRef]
127. Korhonen, J.; Nuur, C.; Feldmann, A.; Birkie, S.E. Circular economy as an essentially contested concept. *J. Clean. Prod.* **2018**, *175*, 544–552. [CrossRef]
128. Flemming, R. *Design Education for a Sustainable Future*; Routledge: Abingdon, UK, 2013.
129. Rotovision. *Experimental Eco-Design*; Brower, C., Mallory, R., Ohlman, Z., Eds.; Rotovision: Mies, MT, USA, 2009.
130. Bhamra, T.; Lofthouse, V. *Design for Sustainability: A Practical Approach (Design for Social Responsibility)*; Routledge: Abingdon, UK, 2007.
131. Tonkinwise, C. Design for Transitions—From and to what? *Des. Philos. Pap.* **2015**, *13*, 85–92. [CrossRef]
132. Calisto Friant, M.; Vermeulen, W.J.V.; Salomone, R. A typology of circular economy discourses: Navigating the diverse visions of a contested paradigm. *Resour. Conserv. Recycl.* **2020**, *161*, 104917. [CrossRef]