sustainability

Review

Literature Review by Scientometric Methods on the Impact of the Circular Economy on Sustainable Industrial Products

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Abstract: The circular economy (CE) is a contemporary concept that includes the use of renewable materials and technologies, making sustainability an important part of corporate management. The paper deals with issues related to the current state of learning and management of the application of circular economy concepts—CE. The main purpose of this work is to identify both the interest of industries in the CE field in terms of the principles of eco-design and eco-innovation of sustainable industrial products, as well as the approach and development of the concept during the pandemic period. The authors performed a scientometric analysis in the Web of Science (WOS) database for the CE field, having two search criteria: sustainability and eco-design. As a result, 66 publications from the last five years were retained. Given the higher number of publications in the last three years, CE was found to be a topical area. Out of the 66 publications, using the PRISMA diagram, the authors identified the eligible articles, excluding 15 of them as being only tangential to the CE field and not applied in the industry. Depending on the high frequency of certain keywords, the authors identified three important directions for the CE approach that corroborate and interpret the results obtained: M—management (1); P—packing (2); and L—Learning (3). Following this approach, the authors determined the focus of the manufacturing industries in terms of applying the concepts and principles of CE, thus being able to contribute to the creation of eco-innovation and eco-design practices of industrial products, especially industrial packaging. The paper will also be beneficial for Ph.D. students who show a certain interest in CE and will help develop the following research directions in this field.

Keywords: circular economy; sustainable design; literature review; industrial design; VOSviewer; WOS; PRISMA; learning

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1. Introduction

The economy is the multitude of human activities conducted in the area of production, distribution, and consumption of material goods and services [1].

Circular economy (CE) is now a "fashionable" idea that is far from comprehensive, coherent, and fully defined [2]. Circularity is a recent element of a new economic paradigm, as one of the fundamental building blocks of sustainability that is mostly connected to development [3]. The words "linear economy" and "circular economy" do not appear to be the best fit. The circular economy may coexist with the linear economic system because the transition to the circular economy can be achieved by extending the "linear" economy through a spiral of processes. Sustainability has become a ubiquitous requirement, determined by global warming and resource scarcity [4].

In theoretical terms, 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*" [5]. According to

Kirchherr et al. [6], the most frequent definition is *"an industrial system that is restorative or regenerative by intention and design"*.

Based on statistical data provided by experts in the field of energy and ecology, there is a great risk of moving rapidly toward the depletion of natural resources. The planet has taken billions of years to collect and store in plants and fossil fuels the energy used today for vehicles, illumination, and other technologies that operate based on energy. The fact that we are using more than our planet can produce is cause for concern.

This study aims to research through scientometric methods the content of the literature published in the Web of Science (WOS) database concerning the influence of CE on sustainable industrial products, and the impact on the environment.

The purpose of the article is to determine key points resulting from the analysis of the literature on CE over the last five years and to identify both the influence of the COVID-19 pandemic period on the development and creation of sustainable and sustainable industrial products and the research that has been carried out in this field.

This work was divided into the following sections, which considered key points for achieving the proposed objectives. Section 1 is the introduction; Section 2 defines the method of research and the analysis of the results obtained. Following the scientometric analysis, 66 articles were selected that dealt with the research directions: CE, sustainability, and eco-design. Depending on the frequency of the keywords, three significant research directions in the field of CE were identified: M—Management, P—Packing, L—Learning. Section 3 discusses these three approaches: M, P, L. Section 4 develops the conclusions obtained in this paper.

Referring strictly to industrial production, we can say that the two concepts, CE and sustainability, are closely related and should work together. On the one hand, sustainability must focus on the development of industrial products and environmentally friendly technologies to conserve natural resources. On the other hand, in recent years, CE has moved mostly in a linear direction, and numerous products break down too easily, cannot be reused, repaired, or recycled, or are produced only for one use. It can be said that CE is a component of the concept of sustainability, through which we can apply principles and procedures to increase the development of eco-products.

2. Research Method

2.1. Literature Review by Scientometric Methods

The scientometric study was carried out based on research performed in the Web of Science (WOS) database. The authors chose only WOS articles for the analysis because, according to the standards of promotion in the academic environment, the quality of the WOS articles had a higher share.

We searched for articles on "circular economy", "sustainability" and "ecologic design". Articles published in each journal before January 2020 were taken under consideration.

The database extracted from the Web of Science was analyzed using the VOS Viewer (VOSviewer version 1.6.16, free software from https://www.vosviewer.com/ (accessed on 5 February 2022)).

Figure 1 shows the steps of looking for and identifying the essential publications for this investigation. The authors followed the instructions of the PRISMA protocol (Preferred Reporting Items for Systematic Reviews and Meta-Analysis), which was developed by an international network of healthcare professionals, to ensure the methodological rigor and quality of the review. The protocol suggests a set of evidence-based items to be reported in systematic reviews and meta-analyses [7,8].

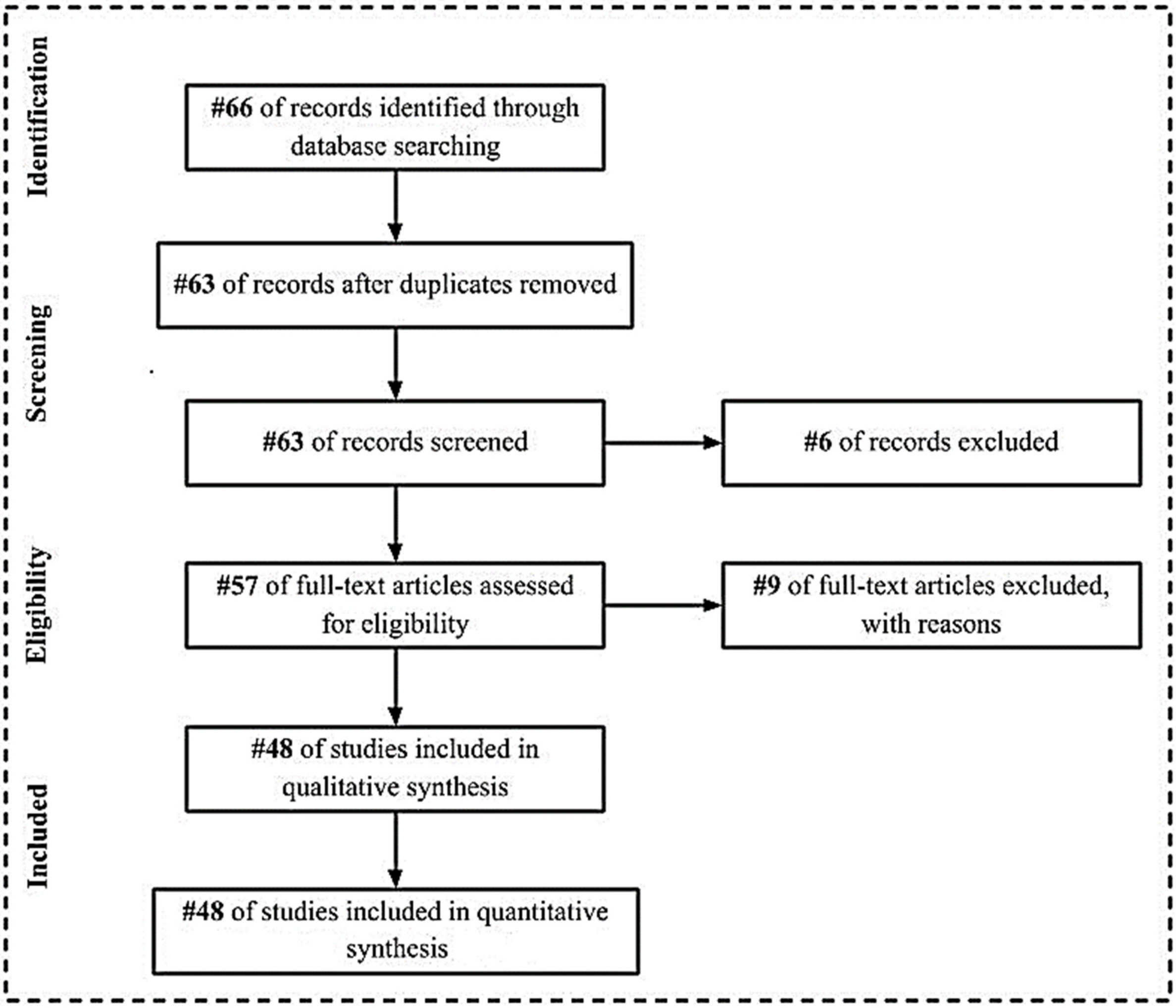

Figure 1. PRISMA flow diagram indicating the number of articles analyzed using the selected systematic review technique.

For the analyzed field of the CE, articles containing the keywords "sustainability" and "eco-design" were searched. For these two established criteria, 66 eligible articles resulted, which were downloaded and analyzed individually by each author of this paper.

In this review, the PRISMA protocol was implemented in four stages:

1. identification of all articles;
2. examination of relevant articles;
3. eligibility assessment;
4. inclusion/exclusion decision.

2.2. Results Analysis

Sixty-six articles were identified and examined to determine if they included the terms "circular economy", "sustainability" and "ecologic design" (identification and examination stage). The initial search also returned articles tangential to a circular economy (namely, the terms that appeared in the list of references or were used in sentences where the circular economy was not the main subject). All publications that were deleted are shown in Appendix A, in which the criteria for their elimination were also established. For example, in one of the eliminated articles, the authors conducted a study on the improvisation of a sustainable microwave oven used at home that works with solar energy.

Two of the authors read the full text of all selected papers (eligibility evaluation step) and chose to delete 15 publications, yielding a final pool of 48 articles. All of the researchers of this review independently evaluated these papers.

The research also revealed a considerable rise in the number of papers investigating the circular economy in the disciplines of sustainability and eco-design over time, Figure 2. The journals with the highest number of published articles were *Sustainability* (14 articles) and the Journal of Cleaner Production (12 articles).

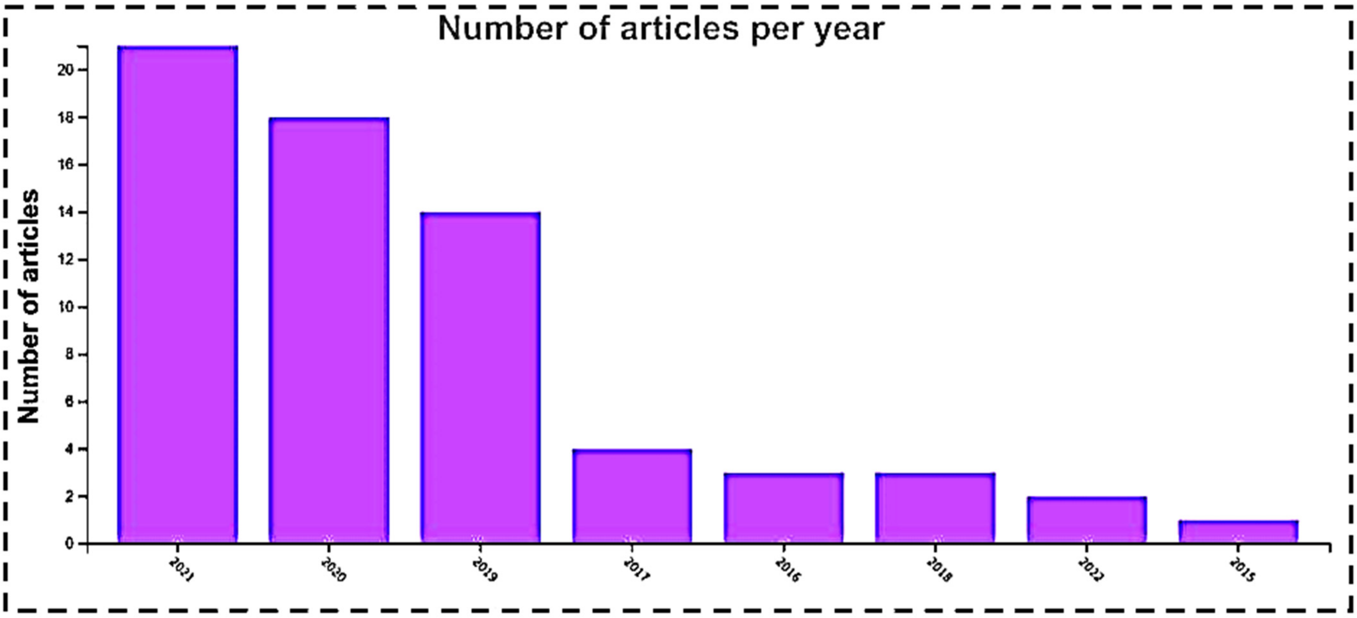

Figure 2. The publication dates of the 66 publications included in our review.

Analyzing and classifying the keywords of the eligible articles according to their frequency, three research directions were identified: Management—M; Packing—P; Learning—L. The resulting concepts map is presented in Figure 3. On the one hand, the M direction represents a concept without which an organization cannot function, and to apply the CE principles there must be very concrete management of the procedures. On the other hand, the P direction represents a critical point for the application of CE principles. According to statistics, industrial packaging that is not managed correctly has a very high impact on the environment and implicitly on the application of the CE concept. The last direction, L, is a stage that should be constantly achieved to be continuous. Thus, learning and applying the methods and techniques for optimizing the CE process must be continuous and constant. Other directions were identified, such as "implementation" or "performance", but we considered that all three directions, M, P, and L, represented a triad of the CE that must work simultaneously.

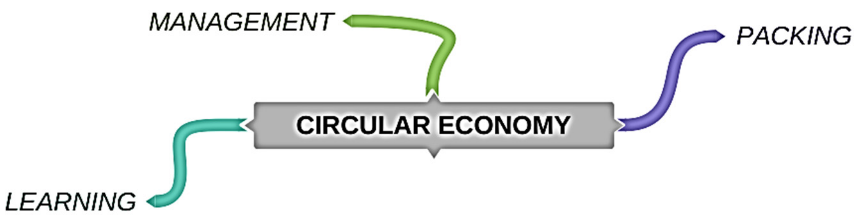

Figure 3. The concept map.

Figure 4 summarizes the identified items, limited to items dealing with CE in the three directions. There were 48 items. The authors analyzed the content of the 48 articles in the three directions: M, P, and L.

Figure 4. Content analysis taking into account authors and types of study [1–47].

2.2.1. Management—M

In recent years, the EU has made the CE a priority, and an environmental management system based on the Eco-Management and Audit Scheme (EMAS) may help companies to achieve this goal by helping them analyze and measure the efficient and sustainable use of resources [9]. Most companies focus their efforts on diminishing emissions by optimizing the material cycle and improving internal production processes.

The era of digital transformations experienced an upsurge in all areas, including the promotion of the transition to a circular economy [10]. Marco Vacchi et al. completed research that used Industry 4.0 technology to develop and execute a circular eco-design model that has been deployed in the Italian ceramic tile manufacturing industry [11]. The model was used in a simulation environment to define five different scenarios of raw material supply, which were then validated operationally at a laboratory scale and in a pilot environment, demonstrating that proper raw material transport system selection significantly improves the product's environmental performance. M. Pieroni et al. [12] developed a tool named the "Circular Economy Business Modeling Expert System" applied within manufacturing companies to systematize practices and advice regarding CE. The application of the expert system demonstrated that companies benefit from inspiration by the best practices regarding circular business modeling.

D. Moreo et al. [13] examined numerous global corporations' business social responsibility (CSR) reports to see how they pursued the traditional components of CSR (environmental, social, and economic) and if CE was part of their corporate strategy. Their analysis showed evidence of proper usage by the companies under analysis concerning CE [14].

Eco-innovation and eco-design applied as tools to support knowledge transfer in the CE context, from university to the manufacturing industrial sector, may provide solutions for the exploitation of manufacturing waste [15].

The ECO-Service Design (ECO-SD) method, which integrates ecologic design and service design to create new ecologically sustainable services [14], can correlate the environmental criteria from the ecological design with a human-centered approach. Other studies illustrated how the use of information technologies—such as product lifecycle management (PLM) in the implementation and maintenance of the CE idea—may help to support and assure a successful process for the circular economy principles [16].

Sometimes, multiple methodologies [17] must be applied to identify sustainable industrial systems, which can be modified, adapted, and increase in sustainability [18]:

(a) material and energy flow analysis to identify the process's improvable flows;
(b) best available techniques analysis to suggest the most appropriate techniques to enhance those improvable flows;
(c) impact analysis to analyze and compare the impacts on persons and ecosystems.

M. Sadee et al. [19] presented a technique for assessing overall environmental performance by combining material flow analysis, material circularity indicators, and life cycle assessment indicators. In their paper [20] they developed a methodology that integrates LCA and eco-design to evaluate the influence of the operating hours of a toy. The result of the eco-design was an approximately 50% impact reduction in the manufacturing phase.

In the context of new product development (NPD), managers should be aware that future clients must be involved in NPD for CE efforts to succeed because they are the most prominent stakeholders in this sector, and consuming habits are the biggest obstacle to NPD based on CE principles [21–23]. D. Evrard et al. [24] proposed an engineering design method that combines technology, business and environmental concerns with legacy tools to design, select and validate CE industrial scenarios.

2.2.2. Packing—P

Plastics have shown the highest growth in demand over the previous few decades, rising from 1.7 million tons in 1950 to 359 million tons in 2018 [25]. They are irresponsible to use, especially in the packing area, have raised many questions over time, and have become one of the most imperative environmental issues that must be solved today [26–28].

According to the literature, plastic materials account for the majority of garbage globally. In terms of waste management performance, only 42% of the 17.8 million tons of plastic packaging trash collected was recycled, with the remainder being landfilled (18.5%) or burnt for energy recovery (39.5%) [25,29].

Product designers and engineers need to become aware that plastic waste from the packaging industry represents a major environmental problem. They have to identify and integrate the environmental factor when designing, redesigning, and developing containers and packaging to make them more sustainable and eco-effective.

Starting from this premise, in their paper, the authors of [30] discussed the implementation and exploration of the possibilities and limitations of CAD/CAE tools in eco-design for an agricultural package, the redesign of the studied package, and a comparative analysis of the existing (commercial) package and the redesign proposal developed.

Singh Intrachooto investigated the usage of solid wastes by 108 small and medium-sized industries (SMEs). Despite concerns about the increasing waste volume from production lines, this study discovered that waste recovery strategies among SMEs are uncommon. The majority of industrial owners resort to selling garbage to legitimate and informal recyclers, as well as dumping leftovers in city receptacles [31].

Closing the loop and employing CE business models are only possible if products and services are built for circularity [32].

2.2.3. Learning—L

Continuous learning for applying CE practices should be carried out across all sectors of the companies engaged in manufacturing and product design. In addition, from a management perspective, this should be set as a goal and objective in that company's evolution.

Engineering learners' student-centered active learning necessitates the hard metacognitive integration of high-level evaluative abilities with discipline-based core knowledge [33]. Long-term learning results should be satisfactory if innovative and effective pedagogic ideas are used to persuade students to engage in systemic design thinking and practice [34].

In their paper, the authors of [34] performed research to assess the efficiency of an innovative systemic learning format in an engineering program at ETH Zurich in terms of immediate learning results and a long-term desire to embrace and implement its theory and practice. The students were motivated and involved and experimented with eco-design aspects in a ski-building workshop.

Their paper [35] described the sustainability experiences using the life cycle assessment perspective in two Latin American higher education institutions (HEIs). They analyzed the sustainability, major challenges, and effectiveness of CE in university campuses.

S. Shahbazi and A.K. Jönbrink [32] suggested a set of general circular design principles to map the company's circular product design ambitions throughout the early phases of product design and development in their article. These recommendations proved to help make decisions. The recommended principles are generic, but they may be altered and detailed based on the product type, material utilized, product development process, environmental management system, environmental and circularity goals, business model innovation, circular strategies, and the organization manufacturing system:

(a) **The "reinvent"** method is connected to paradigm shifts in which physical objects become obsolete by performing the same purpose, which is typically activated by fundamentally different products and/or technology.
(b) **The "rethink and reconfigure"** method is concerned with business model innovation, function, and value delivery to the market, and how customers may use, engage with, and experience the goods.
(c) **The "restore, reduce, and avoid"** technique is related to traditional supply chains (take, make, use, and logistics) and strives to decrease excess consumption, enhance efficiency, and extend product life.
(d) **The "recirculate parts and products"** method refers to the end-of-life and closing-the-loop phases when the analyzed components and products can still be fixed, remanufactured, and reused.
(e) **The "recirculate material" strategy** focuses on recirculating materials that can be recycled and reused.

Legitimacy proves to be a decisive factor in whether the type of CE strategy manufacturers adopt yields ecological benefits [36].

Life cycle assessment (LCA) is an effective tool for evaluating the environmental impact of a product throughout its life cycle. This plays a significant role in product innovation from an ecological perspective [37]. In their study, the authors of [38] assessed five interior LED lighting products using screening techniques to identify the problems and opportunities of integrating LCA in LED lighting eco-design. K. Miettunen et al. [39] and I. Kazancoglu et al. [40] stated that recycling should be a critical part of a holistic eco-design. The actions and strategies for battery sustainability have also seen an upsurge in developed countries, being oriented toward the reduction/recovery of nickel (the key element of these products) [41].

Given the environmental impact of LCA, using eco-design and recyclable materials should be carried out in all spheres of the product's intended use, not only in the industrial sphere. For instance, there are a few aspects related to the use of recyclable materials in the household. J.M.F. Mendoza et al. [42] conducted a study to analyze the impact of using solar cookers instead of conventional microwaves and found that such activities may lead to a transition toward CE.

The full scope of the Industry 4.0 concept should also be taken under consideration in this aspect of CE. For instance, monitoring sustainability performances during the development of the best design solutions can be achieved by using IoT technologies [43]. Sometimes even companies in the information and communication technology sector can build and implement circular economy applications [44,45], but at the same time, there are products such as smart textiles with an emphasis on integrating electronics, and sustainability and recycling issues are rarely addressed [46].

Camara et al. [47] presented an ECO + LCA methodology that provides designers with an easy way to visualize the effect of their design decisions on the final environmental impact. Even a "zero waste" scheme, proposed by Consuelo Nava [48], was found to be a CE goal.

The implementation of CE principles is increasingly recommended to achieve sustainable development goals, and new tools are necessary to support those who practice them, such as decision makers, and to monitor the effects of adopting CE [49]. P. Sacco et al. [50] argued that, in many cases, the CE indicators are not identified and they proposed a company-wide "circularity and maturity" tool. For instance, their studies [51–53] represent a direction in defining concept models of eco-design that help extract indicators from documents and guide designers to consider environmental criteria and evaluate their design.

In addition, product design and development, through collaborative project-based learning in industrial engineering, may be highly relevant for applying CE techniques [54].

Recycling of waste materials has strong positive externalities and, to build a sustainable recycling-oriented CE system, there must be a means to guarantee that externalities can be internalized [55].

3. Discussion

Using a systematic analysis of the literature, this paper revealed how the research in the field of sustainability and eco-design has played a role in promoting CE. Three major and relevant areas were identified to show where the research in the field of sustainability and eco-design has focused so far, and to stimulate debate on the research in the analyzed field.

3.1. Management—M

Over the last decade, the EU has made the circular economy a priority, and an environmental management system based on the Eco-Management and Audit Scheme (EMAS) may help companies to achieve this goal by helping them analyze and measure the efficient and sustainable use of resources [9]. Most companies focus their efforts on diminishing emissions by optimizing the material cycle and improving internal production processes, and from our point of view, if there is no management system in which to develop and monitor the strategies applied for improving CE, the traceability of the measures taken to this end is difficult to monitor and improve.

Concerning the era of digital transformations, which has experienced an upsurge in all areas, including promoting the transition to a circular economy [10], we maintain that this aspect represents a strength for the companies that integrate such tools. Just as Marco Vacchi et al. integrated several Industry 4.0 technologies in a study to develop and apply a circular eco-design model [11], a simulation can be initially attempted, and the model can subsequently be validated operationally at a laboratory scale and in a pilot environment, demonstrating that a proper selection of analyzed scenarios can significantly improve the average environmental performance of the product.

Implementing various tools, such as the "Circular Economy Business Modelling Expert System" applied in manufacturing companies to systematize practices and advice regarding CE, may demonstrate that such companies benefit from inspiration by the best practices regarding circular business modeling [12].

From the university to the manufacturing industrial sector, the tools to support knowledge transfer in the CE context, such as eco-innovation and eco-design, may provide solutions for the exploitation of manufacturing waste [15] and may help extend the application of CE concept. The ECO-Service Design (ECO-SD) method, which integrates ecologic design and service design to create new ecologically sustainable services [14], can also correlate the environmental criteria from ecological design with a human-centered approach.

Studies have shown that the use of information technologies—such as product lifecycle management (PLM) in the implementation and maintenance of the CE concept—may support and ensure an effective process for the circular economy concepts [16], given that the impact of the Industry 4.0 concept has grown in multiple directions.

We agree with the authors of these strategies, who mentioned that sometimes, to identify sustainable industrial systems, various methodologies should be applied [17] that can be changed and adapted to increase sustainability [18]:

(a) material and energy flow analysis to identify the process's improvable flows;
(b) best available techniques analysis to suggest the most appropriate techniques to enhance those improvable flows;
(c) impact analysis to analyze and compare the impacts on persons and ecosystems.

Other methods that combine material flow analysis, such as material circularity indicators and life cycle assessment indicators, comprise an approach for the evaluation of the global environmental performance, and studies showed that the outcome of eco-design was an approximately 50% reduction in the manufacturing phase [19,20]. D. Evrard et al. [24] proposed an engineering design method that combines technology, business and environmental concerns with legacy tools to design, select and validate CE industrial scenarios.

In the case of new product development (NPD), managers should be aware that future consumers must be involved in NPD for CE efforts to succeed because they are the most prominent stakeholders in this sector, and consuming habits are the biggest obstacle to NPD based on CE principles [21–23].

3.2. Packing—P

According to recent subject studies, among all the materials, plastics experienced the fastest growing demand in the last decades, moving from 1.7 million tons in 1950 to 359 million tons in 2018 [25–28]. They are irresponsible to use, especially in the packing area, have raised many questions over time, and have become one of the most imperative environmental issues that must be solved today.

Given that the studies show that plastics account for most of the waste worldwide, it is necessary that product designers and engineers become aware that plastic waste from the packaging industry represents a major environmental problem and move toward the use of eco-materials. Engineers must identify and integrate all major aspects related to the environment when designing, redesigning, and developing containers and packaging to make them more sustainable and eco-effective.

Analyzing the possibilities and limitations of implementing and exploring CAD/CAE tools in the eco-design of a package [30], we can state that they offer a wide range of helpful solutions for designers.

With regard to recycling packaging from the manufacturing industry, Singh Intrachooto investigated 108 small and-medium-sized manufacturers (SMEs) and found concern about the growing waste volume from manufacturing lines, while the waste recovery practices among SMEs were rare.

We argue that the aspects related to the use of CE strategies and methodologies are a key factor that should be introduced as a quality standard. Most factory owners resort to selling wastes to formal and informal recyclers as well as dumping scraps in the city bins [31].

Circular economy business models and closing the loop can be functional only if products and services are designed for circularity [32], and the aspects related to strategies and methodologies of CE use must be rigorously addressed and, at the same time, verified and controlled/audited from the outside.

3.3. Learning—L

Continuous learning for applying CE practices should be carried out across all sectors of the companies engaged in manufacturing and product design. From a management perspective, this should be set as a goal and objective in that company's evolution.

Firstly, learning CE concepts should begin at the stage of student training on design, when the student-centered active learning of engineering students requires challenging metacognitive integration of high-level evaluation skills combined with discipline-based core knowledge [33]. Long-term learning results should be sufficient if innovative and appropriate pedagogic ideas are used to drive students to engage in systemic design thinking and practice in order to achieve general knowledge. The authors of [34] undertook research to evaluate an innovative systemic learning format in an engineering program at ETH Zurich, its success in terms of immediate learning results, and its long-term desire to embrace and implement its theory and practice.

Secondly, gaining new knowledge in product design must be an ongoing process in order to highlight all aspects affecting the environment. Camara et al. [47], for example, provided an ECO + LCA technique that allows designers to easily understand the influence of their design decisions on the ultimate environmental impact. Even a "zero waste" scheme proposed by Consuelo Nava [48] was found to be a CE goal that must be consistently fulfilled.

As provided by S. Shahbazi and A.K. Jönbrink [32], we accept the general circular design principles that map a company's circular product design activities in the early phases of product design and development as a beginning point in product design. These guidelines are generic, but they can be adapted and detailed based on the product type, material used, product development process, environmental management system, environmental and circularity goals, adopted business model innovation, circular strategies, and the company manufacturing system:

- Reinvent strategy;
- Rethink and reconfigure strategy;
- Restore, reduce, and avoid strategy;
- Recirculate parts and products strategy;
- Recirculate material strategy.

Given the environmental impact of LCA, learning to use eco-design and recyclable materials should occur in all spheres of the product's intended use, not only in the industrial sphere. For instance, there are a few aspects related to the use of recyclable materials in the household [42].

Life cycle assessment (LCA) is an effective tool for evaluating the environmental impact of a product throughout its life cycle. This plays a significant role in product innovation from an ecological perspective [37]. In their study, K. Miettunen et al. [39] and I. Kazancoglu et al. [40] stated that recycling should be a critical part of a holistic eco-design, and we support this idea since the design is the initial stage in product development, and it often relies on the engineer's experience.

Concerning the broad evolution of the Industry 4.0 concept, we found that monitoring sustainability performances during the development of the best design solutions can be facilitated using IoT technologies [43]; sometimes even companies in the information and communication technology sector can build and implement CE applications [44,45].

The implementation of CE principles is increasingly recommended to achieve sustainable development goals, and new tools are necessary to support those that practice it, such as decision makers, and to monitor the effects of adopting CE [49]. P. Sacco et al. [50] argued that, in many cases, the CE indicators are not identified, and they suggested another tool at the company level to identify such indicators more accurately.

Product design and development, through collaborative project-based learning in industrial engineering, may be highly relevant for applying CE techniques [54] and may improve the relation with current engineering practices.

4. Conclusions

The potential of a circular economy is significant, and there remain critical areas and open issues that need to be thoroughly addressed by the research in sustainability and eco-design, while looking at perspectives from other disciplines as well.

The sustainable development of humanity requires definite rules regarding the management, extraction, use of natural resources, and integration of exploitation-based waste into a complex, innovative flow.

A circular economy may coexist with the linear economic system since the transition to the circular economy can be done by extending the "linear" economy through a spiral of processes. Global warming and resource constraints have made sustainability a universal imperative.

According to the findings of our systematic review, the empirical research on how design knowledge and expertise may foster a circular economy is currently scarce.

We found that the learning and application of CE practices should constitute a clearly defined and focused goal and objective of gaining CE knowledge and abilities.

Firstly, learning should begin with the stage of student training on design, where innovative and adequate didactic concepts exist to motivate students engaged in systemic design.

Secondly, gaining new knowledge in product design must be an ongoing process, even after graduation, to highlight all CE-specific aspects affecting the environment. We support the idea of developing new tools or guidelines to define strategies and methodologies for applying CE practices and standardization of generic guidelines that can be adopted and adapted by all manufacturers. To this end, we maintain and support strategies based on the following generic directions:

- Reinvention;
- Rethinking and reconfiguring;
- Restoration, reduction, and avoidance;
- Recirculation of parts and products;
- Recirculation of materials.

Certainly, to adapt and develop such strategies and methodologies for applying CE concepts, a very well-defined management tool should exist to achieve the objectives.

Currently, there are various tools, such as the "Circular Economy Business Modelling Expert System" and PLM, but there are other methods, such as ECO-Service Design and LCA methodology, that are very rarely used. NPD managers should also set the main objective regarding CE application and, at the same time, stay focused on the environmental impact of the newly developed products.

The main roles in developing sustainable products are played by the two concepts of eco-innovation and eco-design, which should also become study disciplines within engineering faculties.

Given the broad evolution of the Industry 4.0 concept, we can state that monitoring sustainability performances during the development of the best design solutions can be achieved by using IoT technologies. They can support and incorporate the management tools so that the application impact of CE practices is achieved in a fast and effective manner.

On another note, product packaging has the biggest impact on the CE, especially plastic packaging, when strictly speaking about industrial packaging. However, for several years, it has become the focus of many companies in terms of designing eco-packaging.

We argue that, most likely, the focus is not enough, and we recommend, at least at the company level, standardized tools that can be used. Product designers and engineers need to become aware that plastic waste from the packaging industry represents a major environmental problem. They have to identify and integrate the environmental aspects when designing, redesigning, and developing containers and packaging to make them more sustainable and eco-effective.

The CE is a component of the concept of sustainability through which principles and procedures can be applied to increase the development of eco-products. This will reduce the number of products that break down too easily, cannot be reused, repaired or recycled, or are produced for just one use.

The limitations of this study include the use of a single database, namely, Web of Science, but only this database was used because, according to the standards of promotion in the academic environment, the quality of WOS articles had a higher share.

Another limitation relates to the keywords used to collect studies. For example, search words did not include procedures or methods for eco-designing sustainable products, such as designing for a certain range of products. Owing to the authors' own experience, subjectivity was difficult to avoid and again represents a limitation of the research.

Also, by using only three conceptual terms (CE, sustainability, and eco-design), the research was limited. Scientometric research methods show us quantitative, not qualitative, data.

The authors delivered a critical study of the approach to a circular economy. This study will help develop the next research directions in this field, creating international interdisciplinary teams of researchers who can contribute to learning and improving eco-design strategies. The researchers can use the same research methods for other topics as well. The article will also be of use to Ph.D. students and will be of some interest to practitioners.

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

Appendix A

Table A1. Criteria for the exclusion of publications that were not related to the research of this paper.

No.	Authors	Title	Ref.	Criteria for Exclusion
1.	S. Sehnem, A. de Queiroz, S. Pereira et al.	Circular economy and innovation: A look from the perspective of organizational capabilities	[56]	Research focuses on tools and mechanisms that allow the creation of business models based on the premises of the CE.
2.	M. Aguiar, J. Mesa, D. Jugend et al.	Circular product design: strategies, challenges and relationships with new product development	[57]	It addresses aspects of circular design for new products, but it is not clear what kind of products they refer to.
3.	N. Bocken, L. Strupeit, K. Whalen et al.	A Review and Evaluation of Circular Business Model Innovation Tools	[58]	Although it complies with the established criteria, the procedures by which the operationalization stage can be replicated are missing.
4.	M. Garcia, A. Alonso, M. Tello et al.	Identifying agri-food research priorities for Spain—2017 results	[59]	It is not the object of study of this work, the subject being from the food area.
5.	P. Jiang, E. Dieckmann, J. Han et al.	A Bibliometric Review of Sustainable Product Design	[60]	The authors offer four eco-design directions, but there are no specified procedures by which they can be adapted to various applications.

Table A1. *Cont.*

No.	Authors	Title	Ref.	Criteria for Exclusion
6.	F. Eleonore, P. Tamburrini, M. Franca	Designing Major Appliances: A Decision Support Model	[61]	The redesign criteria restrict the range of products to which it could be applied.
7.	S. Sihvonen, J. Partanen	Implementing environmental considerations within product development practices: a survey on employees' perspectives	[62]	It is not clear how they investigated product development practices based on employee perceptions.
8.	J. Payet	Assessment of Carbon Footprint for the Textile Sector in France	[63]	It is not the subject of study of this work, the authors address the carbon footprint of household clothes and underwear.
9.	M. Watkins, J. Casamayor, M. Ramirez et al.	Sustainable Product Design Education: Current Practice	[64]	The research fits very well on the criterion of "Management," but the geographical area studied is limited to confirm the application of learning methods.
10.	J. Albaek, S. Shahbazi, T. McAloone et al.	Circularity Evaluation of Alternative Concepts During Early Product Design and Development	[65]	It does not refer to what kind of products the tool for evaluating the circularity of a product has been applied.
11.	M. Roffeis, J. Almeida, M. Wakefield et al.	Life Cycle Inventory Analysis of Prospective Insect Based Feed Production in West Africa	[66]	It is not the object of study of this work, the subject being from the food area.
12.	M. Bukhari, R. Carrasco Gallego, E. Ponce-Cueto	Developing a national programme for textiles and clothing recovery	[67]	It is not the subject of study of this work, the authors approaching the management of clothing and textiles in the CE sphere.
13.	F. Aran-Ais, C. Ruzafa-silvestre, M. Carbonell-Blasco et al.	Sustainable adhesives and adhesion processes for the footwear industry	[68]	It is not the subject of study of this paper, the authors addressing aspects of the CE for the manufacture of shoes.
14.	D. Jugend, P. Fiorini, M. Pinheiro et al.	Building circular products in an emerging economy: An Initial Exploration Regarding Practices, Drivers and Barriers Case studies of new product development from medium and large Brazilian companies	[69]	The case study for the three companies is too small to validate the application of CE practices in NPD.
15.	C. Chaudron, M. Faucher, L. Bazinet et al.	The cost is not enough—An alternative eco-efficiency approach applied to cranberry de-acidification	[70]	It is not the object of study of this work, the subject being from the food area.
16.	R. Agrawal, D. Vonodh	Prioritisation of drivers of sustainable additive manufacturing using best worst method	[71]	It is not clear how the data were collected from 40 drivers, for whom the additive manufacturing method was applied.
17.	F. Brones, E. Zancul, M. Carvalho	Insider action research towards companywide sustainable product innovation: eco-design transition framework	[72]	It is not the subject of study of this work. The research was carried out on a company producing cosmetics.
18.	N. Prioux, R. Ouaret, G. Hetreux et al.	Environmental assessment coupled with machine learning for circular economy	[73]	It is not the subject of study of this work. The case study was applied to the field of pretreatment processes for corn and rice straw.

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