 doi:10.20944/preprints201811.0128.v1

Article

DIY Materials and Circular Economy: a case study, educating industrial designers for sustainability

Jimena Alarcón [1]*, Andrea Llorens [2]

[1] Escuela de Diseño, Universidad del Biobío, Concepción, Chile; jimenaal@ubiobio.cl
[2] Escuela de Diseño, Universidad del Biobío, Concepción, Chile; andreall478@gmail.com
* Correspondence: jimenaal@ubiobio.cl; Tel.: +56-9-8288-6046

Abstract: The article presents an experience based on the design of DIY materials (Do-It-Yourself) as a phenomenon that contributes to the circular economy, making use of household waste and organic binders. The development context is the southernmost Industrial Design School in Latin America, where students are educated through the transfer of knowledge emphasized on the experimentation and territory assessment.
Methodology corresponds to the traditional industrial design process, inserting DIY design of materials in the strategic stage. Objective and subjective variables are determined applied in the definition of new materials, being able to determine a range of proposals based on household waste. Citrus × Sinensis, Peperomia caperata (Piperaceae), Radiata pine veneers, among them, which are conceived by students to be self-produced at the user level. The results are materials elaborated based on household waste, exemplified with three types based on organic husks. Beyond findings associated to technique, compatibilities between residual materials and results expressed in materials and catalogs, it is possible to educate future designers on the innovative theme, with the potential to improve life quality of people and their environments.

Keywords: circular economy; education; reuse; sustainability; self-produced materials; waste.

1. Introduction

This study presents the experience of designing self-produced materials with Industrial Design undergraduate students, using identified and classified waste, according to the reality of productive, home and natural environment of Bío-Bío region of Chile. The objective is to integrate new strategic tools in the design management, as well as to conduct design education with social responsibility. Parameters related to sustainability are applied, such as reducing, reusing and recycling [1], from the conceptual view of the generation of Do It Yourself materials (DIY) [2,3].

This type of material obeys a trend that proposes the design of materials at the user level; a movement expanded beyond the creation of products, the design and manufacture of materials without using highly technological equipment [4]. This type of materials is originated based on the experimentation of individual or community self-production [5]. Its appearance-related features can be associated with very artisanal and imperfect, while production is usually low technology [6].

Under the designer professional practice perspective, this learning is linked to manager designer, together with a designer who is capable of promoting product ideas [7]. The integral role that designers deploy just at the beginning when the new consumer product appears, that is, they can determine or predict their environmental, social and technological costs and impacts [8]; which means greater importance, when evidencing that life cycle of all industrial products is determined, between 40 and 60%, by the impact of materials with which it has been manufactured [9]. Because of this, the responsibility and performance of designers have been modified over time; environmental concepts evolve from ecological design to design for sustainability and, more recently, to circular design [10].

2. Economy and circular design: DIY materials.

In this context, the design of DIY materials and the reuse of waste have joint this experience to auto-produce unpublished materials, towards new features with impact on the awareness of the need to contribute to generating life cycles of products suitable for circular economy concepts [11]. In this sense, the material is not only used one time to be discarded but through recycling or reuse, these adverse influences are minimized with the praxis of taking advantage of them.

These emerging materials offer the opportunity to achieve positive social change [12], environmental, economic and even political [13], due to the numerous and the varied opportunities and benefits the application of circular economy concept can contribute to the economy of a country [14]. All activities carried out by people in daily life, generate impact on the environment, for example, transport, feed, sanitize, being elements and processes necessary for them to occur, absorbed by an environment like pollution. According to Ashby [15] (p. 7), "part of this impact, at least, derives from the manufacture, use, and disposal of products, and products, without exception, are made from materials", which come from the exploitation of natural resources, to obtain raw materials that will generate products; same as energy required to be produced, planet resources are limited. In this sense, the strategic and associative link between design and sustainability makes possible to reduce traditional production consequences [16], intervening on from the cradle to the grave paradigm [17], to delay and minimize the arrival of valuable raw materials to waste status. To this extent, sustainable development promotes a circular economy, focusing material on the reusing of resources, promoting synergies between economic sectors and stimulating value chains [18]. However, evidence exposed indicates that current production and consumption model originates waste that, mainly, do not go back to being reused or recycled, being a direct consequence of diverse human activities. Undoubtedly, to promote sustainable development, it is important to promote sustainable manufactures, convert waste into resources, optimal design products, change consumption patterns and increase scientific research and innovation investment [19]. To this extent, the circular economy impact can be significant considering the approach provided by design, promoted by the conception of materials that incorporate waste [20], providing appropriate tools and methods to create innovations that users do not expect, but will eventually perceive as high-value solutions in the future [21].

In public policies, different initiatives promote a more conscious social behavior with the environment. The Kyoto Protocol [22], seeks to generate an international legal status among developed countries aimed at combating climate change and promoting sustainable development. Within the Sustainable Development Goals (SDG), countries are invited to substantially limit waste production before 2030, through its prevention, reduction, recycling and reuse [23]. In the immediate context, according to Chilean legislation, as of 2016, Law 20,920 defines waste as any "substance or object that its generator discards or has the intention or obligation to dispose of in accordance with current regulations" [24] (p. 2), making companies responsible for the useful waste destination. For a generation of DIY materials, where the raw material is based on the recycling of waste, all those units classified as waste are included, both in the design and in the time of use [25] become appreciated source of resources [26]. Its origin is very varied, so it requires prior classification to be used properly in the generation of a new DIY material.

3. Methodological approach for DIY materials design

The DIY material definition is related to its understanding, firstly understanding that it corresponds to the range of matter that uses space, which is observable, measurable and transformable, of artificial origin, natural or a mixture of both. Materials collaborate in satisfying the needs of people and improving cities, with more and better benefits [27].

On the one hand, in this sense their physical-mechanical and chemical characteristics influence, determining structural properties and functional qualities; and, on the other hand, through external attributes, inherent to the expressive and formal sphere where sensory characteristics arise [28]. Historically, the material has been increasingly considered as essential gear to customize multidimensional artifice, where exhaustive problematic is managed by the designer to give presence to the object. This condition makes it capable of performing functions and assuming the role of true engines of innovation, generators of experiences and exaltation of emotions [29].

Various investigations in the field of materials are conclusive for designers to understand how materials influence the design of the product, based on multidimensionality of technique, aesthetics, emotion, sustainability, and meaning. In consideration of this complexity, materials can be selected more responsibly and from the systemic approach concerning their conceptual phase, observing perspective of sensory experience perceptible, through physiognomy and meaning they radiate [30]. Certainly, material appearance affects senses, being able to cause reject or attraction, depending on nature [31]. The matter is transformed into the material when becomes customized part of the product. According to Bramston [32] (p. 6), "Material by itself does not necessarily conform a design, but it does have the capacity to elevate or improve proposal and, as such, deserves our full attention." Therefore, the design of material is also inherent to the creative scenario, where the project of material is valued as independent practice to the conception of the final product [33].

Individuals cohabit permanently in an environment of materials, perceiving them as the essence of what they sensorily capture and experience in everyday life. According to Ashby and Johnson [1] (p. 4), "today, people are looking for sustainable and friendly products, and the job of a designer is to create those products," that strategically and consciously, promote deep and emotional connection with the user. Materials influence the product valuation, due to its sensory qualities recognizable in user affective response [34]. Indeed, materials chosen to form product can play a decisive, quantifiable role in how pleasant or unpleasant it can be for those interacting [35]; valuing an estimation of aesthetic and perceptual virtues.

4. How Industrial Design education integrates the design of materials

Consequently, designers have estimated the idea that material can be designed, showing that knowledge involved in the design is first in people (designers), then in processes (methods); and, finally, in products [36]. So, why the importance to teach Industrial Design students that material design can be part of their performance? In Latin-American and Caribbean (LAC region), the total amount of waste generated per year is 160 million tons, with per capita values ranging from 0.1 to 14 kg/capita/day, and an average of 1.1 kg/capita/day [37].

However, at the user level, policies promoting management for household waste treatment do not include circular economy concepts in this region, these are sent to landfills. In an educational context, there are not enough teaching programs for design of materials, since they are based on project model [38], where virtue is to guide design process systematically, but without registering variations in terms to focus possibilities according to current economic, productive and social scenarios. Therefore, the design sense continues to be focused on final product design and not on materials, services, experiences and other issues of the discipline. Quick action must occur to set the design of materials as an innovation engine. According to Manzini [39], the design of material predates the design of the product.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 6 November 2018 doi:10.20944/preprints201811.0128.v1

Observing methodological model traditionally implemented, interpreted schematically by Prodintec [40], the design of materials could be placed in the strategic definition stage (Figure 1), due to economic, productive, environmental and systemic impact in general, but mainly by its fundamental contributions in the conception of the products.

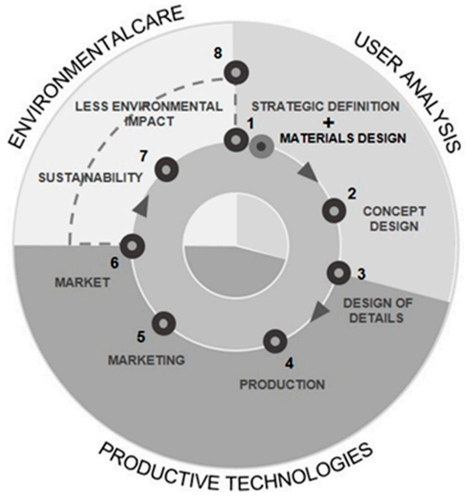

Figure 1. Product design process that incorporates the material design.
Source: Own elaboration, based on Prodintec [40].

Aimed at opening new possibilities for design in these contexts and solving general waste treatment problems in developing countries [41], the pilot experience is implemented in undergraduate students, revealing the design of material as an integral part of product ideation process. Philosophy sustaining this view consists of improving the experience of coexisting -using, coexisting- with products that inhabit an environment where materials define the character of products and living spaces. These should be thought beyond functional and decorative, based on a deep exploration of functional and sensory properties, to achieve the well-being of people. Designers should pay special attention to the properties of materials in contact with user [42]. This requires developing a new design approach, based on fundamental characteristics of materials and consideration of studies that evaluate the perception of users.

For this reason, when new challenges arise, such as reducing the growing waste generation without an ethically controlled destination, we must rethink approaches that connect the material conditions of products with people experiences. Thus, technological development can be focused on the environmental sense and quality of life. As a whole, we put waste out of our sight and from the reach of our mind, without thinking about management implications associated with the destination [43]. This generalized situation constitutes a challenge for a significant development of materials that involves exploring considering innovation as the aim. Here, as important as the production of material, is the generation of positive perception by users. Therefore, this experience proposes a formulation of integration of the design of materials in study programs for industrial designers, through a new approach of design-driven material, evaluating both efficiency and functionality, as well as appreciation in the experience of users.

When people interact with products, emotional relationships arise and designers must be aware of those relationships to create meaningful products. The objective also implies providing knowledge to generate innovative product for environmental sustainability, as well as a novel approach to product design, which integrates and go deeper on material conditions, perceived quality included. Design material becomes an exercise of understanding and observation, to know and understand attributes, potential, and limitations with respect to other materials, so that students can finally be amazed at material experience [44]. When people interact with products, emotional relationships arise and designers must be aware of those relationships to create meaningful products.

The DIY (Do-It-Yourself) movement starts with the design of products and then expands into the design of materials [4]. DIY materials are created from collective or individual practices, often developed with techniques and processes created by the designer [45]. Apply reduce, recycle and reuse material when the useful life of product ends, applying an educational approach that moves from the theory to exploratory and practical [46]. DIY materials generate new experiences, promote sustainability and self-production [47]. It is an active way to react against mass production and promote the development of knowledge through the action [48]. On the other hand, they reflect local identity, since they are elaborated with raw materials, techniques, and resources abundantly available in territories where they are produced, reducing costs, encouraging recycling and strengthening links with a community of origin.

5. Materials and Methods

This experience is developed with the methodological process based on the generation and transfer of knowledge through experimentation and territory assessment. Third-year students coursing Materials Design Workshop in the School of Industrial Design at the Universidad del Bío-Bío, Chile, follow the following stages:

5.1 Collection of waste information

Macro-territorial environment characteristics are studied to obtain a database concerning resources, types of industries, commerce, urban and rural sectors, to find out, define and characterize types of waste according to origins, composition, and potentialities for application in New Materials.

5.2 Strategic definition

Determination of waste to be used in the preparation of new materials, considering the availability of resources (Table 1), user-level workability, capacity to generate management systems to collect these residues, as well as functional potential and sensory.

Table 1. Classification of Residues collected by students

ORGANIC WASTE		INORGANIC WASTE	
Vegetal kingdom	Animal kingdom	Natural	Synthetics
Seeds	Eggshells	Stones	Plastics
Leaves, Branches, rods	Hairs, skin	Clay	Containers and packaging
Orange peels	Bones	Sand	Glass
Walnut shells	Wool	Ceramics	Egg boxes
Cotton		Salt	Fabrics or fibers
Seaweed, shells			Drink cans
Wood, cork			

Source: Self- elaboration

Karana research tool [49], Meanings of Materials (MoM) was incorporated for the selection of materials, which considers the expressive dimension of materials and technological processes. Its purpose is to stimulate design students to systematically involve the consideration of the meaning and sensory qualities in their material selection processes [50].

5.3 Objective and subjective definition of new material

Two large areas are visualized in this process which contains aspects to be considered in the design and development of material; one focuses on the objective qualities and the other on subjective qualities of the material. Both generate interaction between the user and the final product, based on multidisciplinary developments, eliciting knowledge synergy and expertise to address all issues in an integrated manner (Figure 2). In this measure, the objective qualities deal with functional aspects, such as technical, productive, technological and environmental aspects of material, with strategic view based on experimentation and research, to generate innovative concepts in future final products, supported by engineers, chemists, computer technicians, among others, or of the specialty that is required according to the material demands it. Subjective qualities are concerned about sensory aspects that involve users and their reception towards material, conducting market research to define trends and opportunities, sensory and aesthetic evaluations, perceived quality surveys, significance in user studies, participating, among others, psychology, sociology, marketing and statistics disciplines that verify user acceptance and emotional perceptions in the designed materials.

Figure 2. Material design process.
Source: Self-elaboration, based on Karana, E. [49].

5.4 Conceptual design

Consists of an idea generation that ideologically defines proposal of every new material. The process of experience observation focused on nature analysis, evaluation of perceived quality through user studies, solve initial issues of functional and sensory intention.

5.5 Experimentation:

The design process, additionally to technical considerations and derived from external agents of the macro environment, integrates traits from student's intuition, based on the empirical exploratory approach of residues with potential. Self-production process of new material implies integration of tangible and intangible waste capacities. There is a testing and trial stage associated with a search of formats, technical and aesthetic compatibilities, elaboration processes at the user level, besides multidisciplinary cross-linking to obtain original and innovative feasible results.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 6 November 2018 doi:10.20944/preprints201811.0128.v1

6. Results

Results based on household waste shells: examples.

6.1. Material based on eggshell: household waste called chicken eggshell was used. Subjected to potable water washing process, dyed with commercial vegetable dyes and dried at room temperature. Subsequently crushed with home methods until reaching the desired particle size. Then mixtures are made with additives based on glycerol, vinegar, water, and potato starch, to be arranged later in acrylic mold and pressing at moderate heat (180°), in a domestic oven and allow to dry. The bio-composite product is a 150 x 150 x 15 millimeters decorative tile. Cohesive, rough to touch, non-slip, but without superficial, colorful, scentless flaking, which can function as a shaping module for textured frames in vertical walls (Figure 3).

Test prototype 1	Test prototype 2	Combination

Figure 3: Prototypes of materials with eggshell.
Source: Project file.

6.2. Material based on orange peel: using pieces of orange peel (Citrus × Sinensis or Citrus aurantium Sour Orange Group) 2 x 3 millimeters (Figure 4). Approximately, crushed in a domestic blender and then dried in an electric oven at a medium temperature, to have a slow and homogeneous drying process. At the same time, wood veneers (Radiata pine) residues from abundant wood industry in the region. The composite material is made of a core of treated orange peels and wood veneers with use of natural binder made from cornstarch and water. Domestic elements are used to generate weight and pressure for five hours. The result is a decorative biodegradable modular material of 200 x 200 x 5 millimeters thick, which emanates aromatic orange essence, and can be used as a coating for vertical walls with sensorial stimulation properties.

doi:10.20944/preprints201811.0128.v1

Test prototype 1	Test prototype 2	Combination

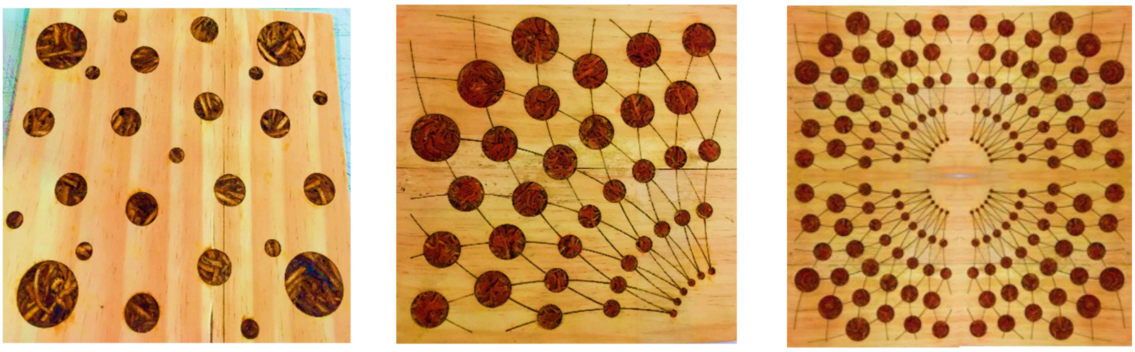

Figure 4: Prototypes of materials with orange peel.
Source: Project file

6.3. Material based on a nutshell: walnut shell (Figure 5), walnut fruit seed (Juglans regia), Crushed in a stone mortar until getting particles of the desired size. The mixture is made with walnut shell particles and a homemade degradable binder made with wheat flour, sugar, vinegar, and water, of transparent nature so as not to intervene in natural shell color. Then, it is placed in a mold with desired counter-shape and subject to moderate pressure and heat in a domestic oven. The drying process is at room temperature. The resulting product is a decorative 350 x 250 x 15 millimeters bio-composite module, Mono-color, non-slip, without aroma, which can be used as decorative coating module for vertical walls.

Test prototype 1	Test prototype 2	Combination

Figure 5: Prototypes of materials with walnut shell.
Source: Project file.

7. Discussion

Studies carried out by users, as well as physical-mechanical tests, allow students to understand the design cycle of material. On the other hand, the preparation of technical folder with description and elaboration process at user level makes the proposal replicable and, therefore, transferable. This document contains the necessary ideas for an individual to implement the creation of DIY materials at home or in the community. Projection towards this last case involves management of resources, through a program that organizes the community to provide its household waste according to reuse standards. It is interesting to value the decreasing time concept of psychological obsolescence of products and find, in the design of materials, the opportunity to reduce contamination levels covered from strategies to devise new waste interpretations.

The design of materials can be considered as progression instrument, both intellectual and disciplinary, fascinating and seductive. It turns out to be the active practice of learning and understanding, through material experience, which then becomes an essential vehicle to design artifacts from materials.

This approach to materials and processes is inserted in the usual design scenario, defined by skills that designers dominate, integrating epistemic and dogmatic character of experience. It is a new alternative to traditional selection of materials from the industry since it gives them autonomy from ideation to self-production. This way, designers go through a new path in discipline and labor fields, creating significant experiences of singular materials, being a reference in the innovation to generate their projects from renewed material perspective. Ideally, this type of teaching should be integrated into curricula as a driver for more autonomous professionals, new business opportunities, generation of a higher number of initiatives according to social innovation programs.

8. Conclusions

Pedagogical experience of education regarding the design of undergraduate materials demonstrated students' abilities to understand the environmental, economic and social benefits of an emerging phenomenon, the DIY materials. Two positively aspects valued by students were: (a) to recognize self-production with waste, as possibility inserted in circular economy model, where components and materials recirculate and continue to contribute to economy, giving context to this perspective renewed discipline; (b) the possibility of contributing responsibly to a poorly organized society in relation to the control of production and waste management.

The self-produced materials with the use of waste, contribute to the need to generate environmental awareness; and they provide benefits due to the lower impact on the expense of producing highly technical materials. At the same time, there are more eloquent reasons to give a second life to waste, minimizing the use of non-renewable resources, reducing the dependence of developed countries on imports of raw materials, reducing the demand for energy to produce, as well as, emissions caused by production and use of materials.

Designers must know very well these definitions, consistent with the emergence of DIY materials, waste recycling and the use of non-conventional materials for self-production while developing skills to manage them through social innovation or commercial level. It opens new creative development line in labor field of designers, originating potential impact on the professional performance of discipline from a sustainable perspective, focused on new ventures and business ideas, fostering competitiveness through innovation, showing their ability to adapt to changing production environments.

Author Contributions: J.A. is the main author of the paper, and carried out the primary research. A.LL. provided academic guidance for the research and provided feedback on structure and content of the paper. JA was in charge of analyzing the data and supervised the process and contributed to reviewing the paper totally. A.LL. produced the images for this manuscript. Both authors read and approved the final manuscript.

Funding: "This research received funding from the National Commission of Scientific and Technological Research (CONICYT), Chile."

Acknowledgments: The authors are grateful for the National Commission of Scientific and Technological Research (CONICYT), Chile, N ° REDI170581, "Perceived value of recycled raw materials, applied to the generation of new materials: design for social acceptance and circular economy."

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

References

1. Ashby, M.; Johnson, K. Materials and Design. The Art and Science of Material Selection in Product Design, 3rd ed.; Elsevier: Oxford, UK, 2014.
2. Rognoli, V.; Bianchini, M.; Maffei, S.; Karana, E. DIY Materials. In Virtual Special Issue on Emerging Materials Experience. Mater Des 2015 vol. 86, 692-702.
3. Ayala-García, C.; Rognoli, V.; Karana, E. Five Kingdoms of DIY Materials for Design. In Proceedings of EKSIG 17 - Alive. Active. Adaptive - Experiential Knowledge and Emerging Materials, The Netherlands, 19-20 June 2017.
4. Brownell, B. DIY Design Makers Are Taking On Materials. The Journal of the American Institute of Architects 2015. Available online: https://www.architectmagazine.com/technology/diy-design-makers-are-taking-on-materials_o (accessed on 18 July 2018).
5. Rognoli, V.; Ayala-Garcia, C. Materials Activism. New hybrid scenarios between design and technology. Cuaderno 70, Cuadernos del Centro de Estudios en Diseño y Comunicación. Ensayos, 2018, 70, 105-115.
6. Rognoli, V.; Ayala, C.; Parisi. S. The material experiences as DIY-materials: self-production of wool filled starch-based composite (NeWool). Making Futures Journal 2016, vol. 4, 1-9.
7. Alarcón, J.; Lecuona, M. Design management to increase small and medium multisector enterprises (SMEs) competitiveness: interdisciplinary experience with public funding. In Proceedings 7th International Conference on Education and New Learning Technologies, Barcelona, Spain, July 2015. Edulern15: IATED, Vol.7, N°7, pp. 3067-3075.
8. Brezet, H.; van Hemel, C. Ecodesign: A Promising Approach to Sustainable Production and Consumption; UNEP and TU Delft: Paris, France, 1997.
9. Van Hemel, C.; Cramer, J. Barriers and stimuli for ecodesign in SMEs. J Clean. Prod. 2002, 10(5), pp 439-453.
10. Moreno, M.; De los Rios, C.; Rowe, Z.; Charnley, F. A Conceptual Framework for Circular Design. Sustainability 2016, 8(9), 937; Doi: 10.3390/su8090937
11. Wastling, T.; Charnley, F.; Moreno, M. Design for Circular Behaviour: Considering Users in a Circular Economy. Sustainability 2018, 10(6), 1743; Doi: 10.3390/su10061743
12. Drazin, A.; Küchler, S. The Social Life of Materials, 1st ed.; Bloomsbury: London, UK, 2015.
13. Karana, E.; Fisher, T.; Kane, F.; Giaccardi, E. Editorial: Material-Enabled Changes in Design Research and Practice. Presented at Design Research Society (DRS), U. of Limerick, Ireland, June 2018. Doi: 10.21606/dma.2018.024
14. Oncioiu, I.; Căpuşneanu, S.; Türkeș, M.C.; Topor, D.I.; Constantin, D.-M.O.; Marin-Pantelescu, A.; Ștefan Hint, M. The Sustainability of Romanian SMEs and Their Involvement in the Circular Economy. Sustainability 2018, 10, 2761. Doi: 10.3390/su10082761
15. Ashby Michael F. Materials and the Environment Eco-Informed Material Choice. 1st ed.; Elsevier: Oxford, UK, 2009. p. 7.
16. Papanek, V. Design for the Real World. Human Ecology and Social Change. 2nd ed.; Thames y Hudson, London, UK, 1984. pp.394.
17. Braungart, M.; McDonough, W. Cradle to Cradle, McGraw-Hill / Interamericana S.A., Madrid, España, 2005
18. Ellen MacArthur Foundation. Smart Material Choices, The circular design guide (2016). Available online: https://www.ellenmacarthurfoundation.org/assets/design/Materials_choices_Final.pdf (accessed on 14 August 2018).
19. European Commission. Closing the loop: Commission adopts ambitious new Circular Economy Package to boost competitiveness, create jobs and generate sustainable growth. Cerrar el círculo: la Comisión adopta un ambicioso paquete de nuevas medidas sobre la economía circular para impulsar la competitividad, crear empleo y generar crecimiento sostenible. Briefing Document, 2015. Available online: http://europa.eu/rapid/press-release_IP-15-6203_es.htm (accessed on 3 august 2018).
20. Karana, E.; Pedgley, O.; Rognoli, V. On Materials Experience. Des. Issues 2015. 31(3), 16-27. Doi: 10.1162/DESI_a_00335
21. 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 (5), 308–320, http://dx.doi.org/10.1080/21681015.2016.1172124
22. Cepal, ECLAC. Naciones Unidas. Racionalidad económica de los mecanismos de flexibilidad en el marco del Protocolo de Kyoto. Santiago, Chile, 2000. Available online:

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 6 November 2018 doi:10.20944/preprints201811.0128.v1

https://www.cepal.org/prensa/noticias/comunicados/7/6147/cambioclimatico2.pdf (accessed on 26 july 2018).
23. Cepal, OCDE, Naciones Unidas. Evaluaciones del desempeño ambiental Santiago, Chile, 2016. Available online: https://repositorio.cepal.org/bitstream/handle/11362/40308/S1600413_es.pdf (accessed on 30 july 2018).
24. Adapt Chile. Antecedentes del manejo y gestión de residuos en Chile. Taller intensivo gestión de residuos para la Red Chilena de Municipios ante el Cambio Climático. Red CircaBC, UE. Santiago, Chile, 2016. Available online: https://circabc.europa.eu/sd/a/05d21118-7d52-47f9-89bd-1b7c716a1e62/Introduction%252c%20Antecedentes%20del%20Manejo%20y%20Gesti%25c3%25b3n%20de%20Residuos%20en%20Chile.pdf (accessed on 12 july 2018).
25. Giaccardi, E.; Karana, E. Foundations of Materials Experience: An Approach for HCI. In Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems CHI ´15. Seoul, South Korea, April 2015. ACM Press: 2447-2456.
26. Ayala-García, C.; Rognoli V.; Karana E. Five Kingdoms of DIY Materials for Design. Presented at the EKSIG 2017 Conference, Alive-Active-Adaptive. Experiential Knowledge and Emerging Materials, Amsterdam, The Netherlands, June 2017.
27. Mejía, C. Materiales en Diseño Industrial, una herramienta metodológica para el diseño de materiales. Iconofacto 2010, 6 (7), pp. 108-117.
28. Lefteri, C. Materials for Inspirational Design. RotoVision: East Sussex, UK, 2007.
29. Rognoli, V. Materiali per il design: espressività e sensorialità. Polipress: Milán, IT, 2005.
30. Ayala-García, C.; Patiño, L. Estrategias para mejorar las prácticas de la enseñanza y el aprendizaje de los materiales y los procesos para el diseño de productos en Colombia. MasD 2015, 8 (14). Doi: 10.18270/masd.v8i15.114
31. Alarcón, J.; Llorens, A. Inter-lazos: texturas habitables desde la emocionalidad. Revista 180 2016, 37, 22-25.
32. Bramston, D. Bases del diseño de producto 01: de la idea al producto. Parramón: Barcelona, Spain, 2010, vol. 2, pp 80.
33. Alarcón, J.; Parra, X.; Droguet, C. Tableros en base a residuos de cebada provenientes de la industria agroalimentaria de Chile y adhesivos naturales: experiencia de una calidad percibida. Interciencia 2017, 42 (6), 364-369.
34. Karana, E.; Hekkert, P.; Kandachar, P. Assessing Material Properties on Sensorial Scales. Presented at ASME 2009, International Design Engineering Technical Conferences and Computers and Information in Engineering. San Diego, USA, January 2009. Doi: 10.1115/DETC2009-86756
35. Jordan, P. Designing Pleasurable Products. An Introduction to the New Human Factors. 1st ed. Taylor and Francis: London, UK, 2002.
36. Cross, N. Design Research: A Disciplined Conversation. Des Issues 1999, 15(2), 5-10. Doi: 10.2307/1511837
37. Hoornweg, D.; Bhada-Tata, P. What a waste. A Global Review of Solid Waste Management. Urban Development Series, No. 15. World Bank: Washington, USA 2012 Available online: https://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1334852610766/What_a_Waste2012_Final.pdf (accessed on 8 July 2018).
38. Munari, B. ¿Cómo nacen los objetos?, 1º ed. español. Gustavo Gili: Barcelona, España, 1983.
39. Manzini, E. La Materia de la Invención. Materiales y Proyectos. CEAC: Barcelona, España, 1993.
40. PRODINTEC. Diseño Industrial, Guía Metodológica Predica. Fundación Prodintec: Guijón, España, 2006. Available online: http://adp.cat/web/wp-content/uploads/guia_metodologica_predica.pdf (accessed on 3 august 2018).
41. Alpay, E. Development Patterns of Industrial Design in the Third World: A Conceptual Model for Newly Industrialized Countries. J Des Hist 1997, 10(3), 293–307. https://doi.org/10.1093/JDH/10.3.293
42. Sørensen, J. Measuring Emotions in a Consumer Decision Making Context: Approaching or Avoiding. Working Paper Series Nº 20. Department of Business Studies, Aalborg University. Denmark, 2008 pp. 41
43. Hoornweg, D.; Bhada-Tata, P.; Kennedy, C. Waste production must peak this century. Nature 2013, 502, 615-617.
44. Karana, E.; Barati, B.; Rognoli, V.; van der Laan, A. Material driven design (MDD): A method to design for material experiences. Int. J. Des. 2015, 9(2), 35-54.

45. Rognoli, V.; Ayala-García, C. Materia emocional. Los materiales en nuestra relación emocional con los objetos. Revista Chilena de Diseño 2018, rchd: creación y pensamiento, 3(4), 1-15.
46. Parisi, S.; Rognoli, V.; Sonneveld, M. Material Tinkering. An inspirational approach for experiential learning and envisioning in product design education, Des. J. 2017, 20: sup1, S1167-S1184, Doi: 10.1080/14606925.2017.1353059
47. Rognoli, V.; Ayala-García, C.; Parisi, S. The emotional value of Do-it-yourself materials. In Proceedings of 10th International Conference on Design & Emotion, Amsterdam, The Netherlands, September 2016; pp. 233-241.
48. Schön, D. The reflective practitioner: How professionals think in action. Basic Books: New York, USA, 1983.
49. Karana, E. Meanings of Materials. Ph.D. Thesis, Faculty of Industrial Design Engineering, Delft University of Technology, The Netherlands, 2009.
50. Karana, E.; Hekkert, P.; Kandachar, P. A Tool for Meaning Driven Materials Selection, Mater Des 2010, 31 (6) 2932-41.