SYSTEMATIC BIBLIOGRAPHICAL REVIEW AND GUIDELINES ON ADDITIVE MANUFACTURING/3D PRINTING ORIENTED TO SUSTAINABILITY

REVISÃO BIBLIOGRÁFICA SISTEMÁTICA E DIRETRIZES SOBRE MANUFATURA ADITIVA/IMPRESSÃO 3D ORIENTADA À SUSTENTABILIDADE

REVISIÓN SISTEMÁTICA DE LA LITERATURA Y DIRECTRICES SOBRE FABRICACIÓN ADITIVA/IMPRESIÓN 3D ORIENTADA A LA SOSTENIBILIDAD

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ABSTRACT

Due to the technologies diversity on the rise nowadays, it is becomes necessary to investigate how to use them in sustainable practices. The present study is a Systematic Bibliographic Review (SBR) that verified how Additive Manufacturing/3D Printing technology is being associated with sustainability in scientific productions in Brazil. The sixteen (16) selected papers were published in Encontro de Sustentabilidade em Projeto (ENSUS), Congresso Brasileiro de Pesquisa e Desenvolvimento em Design (P&D Design), Simpósio de Design Sustentável (SDS) annals and Mix Sustentável magazine, between the years 2018 to 2023. The results show (1) papers analysis, aiming to identify its central themes, most recurrent were: Product-Service System (PSS), Waste Reduction, Ecodesign and Recycling; (2) Keywords definition, most used being "3D Printing", "Additive Manufacturing", "Biomimicry", "Filaments" and "Recycling"; (3) understanding studies focus through Design for Sustainability strategies; (4) guidelines for applying 3D printing sustainably.

KEYWORDS

Additive Manufacturing; 3D Printing; Sustainability; Systematic Bibliographic Review.

RESUMO

Com a diversidade de tecnologias em ascensão na atualidade, torna-se necessário investigar como utilizá-las em práticas sustentáveis. O presente trabalho trata-se de uma Revisão Bibliográfica Sistemática (RBS) que verificou como a tecnologia de Manufatura Aditiva/Impressão 3D está sendo associada à sustentabilidade em produções científicas no Brasil. Os dezesseis (16) artigos selecionados foram publicados em anais do Encontro de Sustentabilidade em Projeto (ENSUS), Congresso Brasileiro de Pesquisa e Desenvolvimento em Design (P&D Design), Simpósio de Design Sustentável (SDS) e na Revista Mix Sustentável, entre os anos de 2018 e 2023. Os resultados apresentam (1) análise do artigo, objetivando identificar seus temas centrais, os mais recorrentes foram: Sistema Produto-Serviço (PSS), Redução de Resíduos, Ecodesign e Reciclagem; (2) definição de palavras-chave, sendo as mais utilizadas "Impressão 3D", "Manufatura Aditiva", "Biomimética", "Filamentos" e "Reciclagem"; (3) compreensão do foco dos trabalhos mediante estratégias do Design para a Sustentabilidade; (4) diretrizes para aplicar a impressão 3D de modo sustentável.

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PALAVRAS-CHAVE

Manufatura Aditiva; Impressão 3D; Sustentabilidade; Revisão Bibliográfica Sistemática.

RESUMEN

Con la diversidad de tecnologías en auge hoy en día, es necesario investigar cómo utilizarlas en prácticas sostenibles. Este trabajo es una Revisión Bibliográfica Sistemática (RBS) que investigó cómo la tecnología de Fabricación Aditiva/Impresión 3D está siendo asociada a la sustentabilidad en producciones científicas en Brasil. Los dieciséis (16) artículos seleccionados fueron publicados en los anales del Encontro de Sustentabilidade em Projeto (ENSUS), del Congresso Brasileiro de Pesquisa e Desenvolvimento em Design (P&D Design), del Simpósio de Design Sustentável (SDS) y de la Revista Mix Sustentável, entre 2018 y 2023. Los resultados muestran (1) análisis de los artículos, con el objetivo de identificar sus temas centrales, siendo los más recurrentes: Sistema Producto-Servicio (PSS), Reducción de Residuos, Ecodiseño y Reciclaje; (2) una definición de palabras clave, siendo las más utilizadas "Impresión 3D", "Fabricación Aditiva", "Biomimética", "Filamentos" y "Reciclaje"; (3) una comprensión del enfoque de los trabajos a través de estrategias de Diseño para la Sostenibilidad; (4) directrices para aplicar la impresión 3D de forma sostenible.

PALABRAS CLAVE

Fabricación Aditiva; Impresión 3D; Sostenibilidad; Revisión Sistemática de la Literatura.

1. INTRODUCTION

In a world with increasingly evident social and environmental problems, affecting the relationship between the environment, human beings and other species, it is essential to turn attention to actions linked to sustainability, reevaluating forms of production and consumption, in an attempt to minimize negative impacts.

In the production and consumption model adopted, mainly since Industrial Revolution in 19th century, natural resources waste generates high levels of residue, which in 2018 already reached 1.3 billion tons per year across the planet, including mining, livestock, agriculture, industries, civil construction, demolition and urban solids, and with the depletion of such riches there is a tendency towards scarcity and depletion (Sampaio et al., 2018).

Therefore, manufacturing systems encompass socio-environmental factors and consequences, as they depend on natural resources, such as raw materials, inputs and/or energy, causing, in addition to waste, other health risks (Riul; Silva; Ribeiro, 2011).

Given this context, it is necessary to seek more sustainable standards for both production and consumption, as proposed in the twelfth (12th) Sustainable Development Goal of United Nations (2015), which is possible by strengthening scientific and technological capabilities.

Regarding technologies related to production processes, 3D Printing, an Additive Manufacturing system in which material is gradually added in several layers to make a physical object based on a digital model (Morandini; Del Vechio, 2020), emerges as an alternative that can be aligned with strategies in line with environmental requirements, such as reducing the use of materials and electrical energy (Manzini; Vezzoli, 2002).

The aforementioned manufacturing method also fits into the trends of bringing people and things together, reducing the need for transportation, and sharing instruments and equipment, avoiding excess products (Manzini, 2008).

Recognizing that the technology in question has a promising character in the field of sustainability and to encourage research uniting these themes, this study seeks to investigate, with the aim of exposing guidelines for practice: how Additive Manufacturing/3D Printing is being linked to sustainability in scientific studies?

2. DESIGN AND SUSTAINABILITY

When approaching Design and sustainability, it is essential to understand some relevant concepts. The following topics are sustainable practices in the environmental dimension present in the results of this research, which is why they are used for theoretical basis.

• ECODESIGN

Ecodesign is characterized by considering the entire life cycle, involving energy, material and spatial impacts, in the development of products, systems, services or infrastructure, directing projects with an interest in eco-efficiency (Platchek, 2012).

To carry out projects based on ecodesign, it is crucial to consider some guidelines, including (Pazmino, 2007):

- Reduce the use of natural and energy resources;
- Use inexhaustible, non-damaging, recycled, recyclable and/or renewable materials;
- Use only one material;
- Reduce weight and volume;
- Minimize production processes;
- Increase safety and durability;
- Eliminate packaging or design it to be recyclable or reusable;
- Facilitate maintenance and repairs;
- Enable the replacement of components or refills.

As fundamental objectives, ecodesign seeks to reduce consequences for the environment, reduce production costs and promote a competitive advantage for companies, in a market in which the appeal for sustainable development grows increasingly, bringing contributions at a global level, due to the capacity to extract raw materials tends to be exhausted quickly (Menezes; Vilaça; Reis, 2010).

• PRODUCT-SERVICE SYSTEM (PSS)

A Product-Service System (PSS) consists of material products together with intangible services, designed so that together they satisfy the specific needs of users, while also aiming to achieve sustainable goals (Brandstotter et al., 2003).

There are three categories of PSS, each with specific activities, they are (Tukker, 2004):

- Product-oriented services: service related to the product and advice + consultancy;

- Use-oriented services: product rental, rental or sharing of products and product grouping;
- Result-oriented services: management/outsourcing of activities, payment per unit of service and functional results.

The essential aspects of eco-efficient PSS innovations are: support in an economic model that has satisfaction as its focus, meeting specific satisfaction demands, and the basis on the interactions of stakeholders, enabling radical innovations such as new relationships and partnerships within a certain productive network of satisfaction (Vezzoli et al., 2018).

• WASTE REDUCTION

Waste refers to a vast group of materials discarded by different social agents, generated by the many activities of human beings, such as agriculture, livestock farming, mining, among others (Sampaio et al., 2018).

In general, to reduce such waste it is necessary to change the patterns in which society produces and consumes goods, with actions that include waste control, product reuse and recycling (Ribeiro; Besen, 2007).

This reduction can start with simple actions such as using cloth napkins, not using plastic bags and straws and avoiding food waste, thus contributing to the rationalization of nature's resources (Pozzetti; Caldas, 2019).

In addition to education for responsible consumption, covering all sectors, adequate management of natural capital is essential, an action that needs to be taken and maintained in companies and also in public administration (Figueiredo; Nascimento, 2021).

• ADDITIVE MANUFACTURING/3D PRINTING

The timeline of 3D Printing begins in the 1980s, with the patent application for a rapid prototyping system by Japanese doctor Hideo Kodama, from Nagoya Municipal Industrial Research Institute. Describing this technology as "a vat of photopolymer material (type of resin), with exposure to UV light, which stiffens the part, producing a certain model in layers" (Figure 1). However, the registration was not successful (Lonjon, 2017).

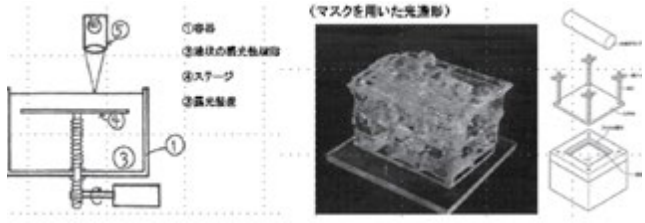

Figure 1: Photopolymer material vat with UV light exposure, by Hideo Kodama.
Source: Institute of Electronics, Information and Communication Engineers [IEICE] (2014).

3D Printing is a manufacturing process through gradual addition of material in layers, receiving information from a 3D computer representation of the component. The stages of this production means can be listed as follows (Carvalho; Volpato, 2017):

(1) Three-dimensional (3D) modeling;
(2) Conversion of the three-dimensional geometric model to a format suitable for printing;
(3) Slicing and delimiting support structures and techniques for material to be deposited;
(4) Object manufacture on 3D printer;
(5) Post-treatment.

Figure 2 illustrates how this process occurs.

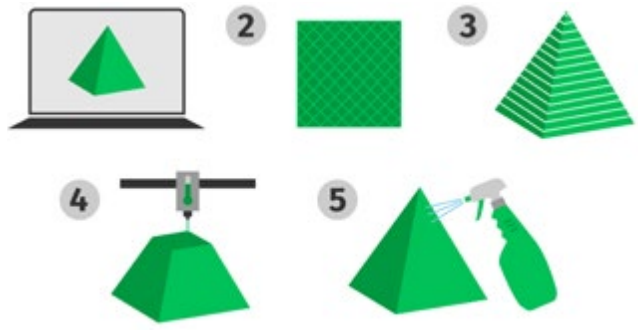

Figure 2: 3D printing steps.
Source: Authors (2023).

There are several types of Additive Manufacturing technologies and, consequently, 3D Printing techniques, both indicated with their acronyms by the standard "ISO/ASTM 52900-15: Standard Terminology for Additive Manufacturing" (Mousapour, 2020).

3D printing is present in several areas such as Medicine: transplants with personalized structures for each patient; Biology: researchers can study types of fossils or bone structures through copies; History: replicas of value or importance items from other centuries are capable of being

produced; Nutrition: food solutions can be developed in laboratory; Robotics: improvements to mechanical parts and electronic components; Design: designing higher quality prototypes for projects (Erickson, 2012).

Checking so many examples, it is clear how 3D Printing has revolutionized the market and even science on a global level, contributing to the advancement of various segments. In this scenario, it becomes of great relevance to understand it based on sustainable precepts, which are capable of making it less harmful to environment, since sustainable development has been established as a goal for contemporary society and new production processes must be aligned with these objectives.

• METHODOLOGICAL PROCEDURES

This research can be classified, with regard to its purpose, as pure (Gil, 2008), as it seeks to produce scientific knowledge by investigating the state of art about relation between 3D printing and sustainability, but without claiming real applications and consequences. In a philosophical conception, it can be seen as pragmatic, because it comes from actions consequences and is oriented towards practice in the real world (Creswell, 2010). Its nature is mixed as it includes collection, analysis and integration of qualitative data, referring to papers content, and quantitative, relating to percentages of subjects covered in them (Sampieri, Collado; Lucio, 2013). The research is also characterized, in terms of scope, as descriptive (Gil, 2008), as it reports how interest themes are treated in the academic studies evaluated.

It is defined as a Systematic Bibliographic Review (SBR), a verification model that highlights its steps, making it possible to track the criteria taken into consideration for execution, thus allowing other researchers to be able to replicate it (Santos, 2018).

Figure 3 shows how methodological processes are organized.

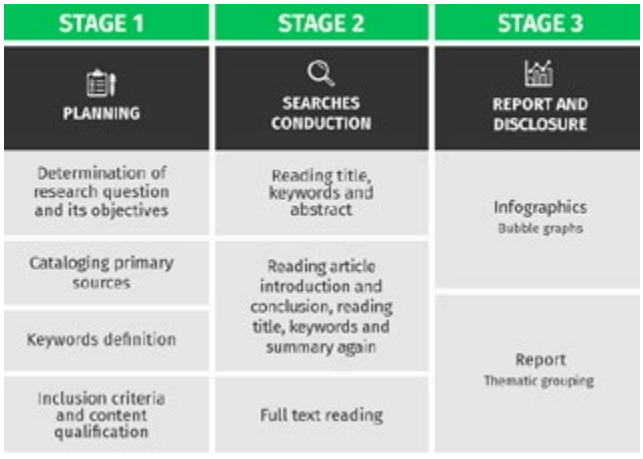

Figure 3: Methodological flowchart.

Source: Adapted from Santos (2018).

In Phase 1, with research question already defined, presented previously in the introduction topic, the sources for searching for papers were determined, being annals those events/journals: Encontro de Sustentabilidade em Projeto (ENSUS), Mix Sustentável Magazine - from the Federal University of Santa Catarina (UFSC) -, Congresso Brasileiro de Pesquisa e Desenvolvimento em Design (P&D Design) and Simpósio de Design Sustentável (SDS), covering the period from 2018 to 2023. The keywords used were "Impressão 3D" and "Manufatura Aditiva", also in english: "3D Printing" and "Additive Manufacturing", since some sources have studies in that language. The criterion for screening papers was that scope should concern Additive Manufacturing/3D Printing associated with sustainable solutions.

Table 1 presents the systemic survey with amount of publications found and how many were selected, after reading the title, keywords, introduction and conclusion, as described in Phase 2, from each database, as well as papers total number.

TABLE 1: Systemic Survey

Data Base	Publications found	Selected publications in screening
ENSUS	13	9
MIX SUSTENTÁVEL	4	4
P&D DESIGN	7	2
SIMPÓSIO DE DESIGN SUSTENTÁVEL	1	1
TOTAL	**25**	**16**

Source: Authors (2023).

Thirteen (13) papers were found from ENSUS and nine (9) were selected, as the others were also published, with their more complete contents, in magazine included in the review, two (2) of which were from 2019, one (1) from 2020, two (2) in 2021, one (1) in 2022 and three (3) in 2023, in Revista Mix Sustentável four (4), one (1) from 2019, two

(2) from 2021 and one (1) from 2023, from P&D Design seven (7), but only two (2) were chosen, following the established criteria, one (1) from 2018 and one (1) from 2022, and in SDS one (1), from 2019.

After reading full studies text, a classification was carried out based on guiding themes of each of them, with respective percentages structured in infographics, following a thematic grouping report, a strategy focused on describing main various themes characteristics, but about a common research problem (Santos, 2018), and development of a framework with guidelines for sustainable practices in the context of 3D printing, as determined in Phase 3. This investigation will be presented in below topic.

3. RESULTS AND DISCUSSIONS

With the completion of Planning and Conducting Search phases, an investigation began on the previously selected papers, with intention of recording sustainable themes that were associated with Additive Manufacturing/3D Printing, also based on subjects discussed in theoretical references. The results were divided into databases, publication year, title, authors and central theme(s) (**Chart 1**).

Through this investigation it was noted that there is a trend towards some themes and following what was determined in Phase 3, Report and Disclosure, themes and their quantities were gathered in a bubble chart (Figure 4).

Figure 4: Central themes of studies.

Source: Authors (2023).

The results indicated Product-Service System as five (5) papers theme, Ecodesign as four (4), Recycling and Waste Reduction as three (3) each and Sustainable Development as only two (2).

In studies centered on Product-Service System, the practices were focused on health and veterinary areas, in manufacture of prostheses, orthoses, among others, and ways of distributing them to users, which may include laboratories, thus offering services. Ecodesign was approached based on products improvement, in aspects such as customization, flexibility, lightness and resistance, and Waste Reduction was mostly linked to civil construction, in cementitious materials design. Recycling was related to creation of filaments derived from waste, such as polymers and wood, and Sustainable Development through residential projects analysis and businesses mapping that include 3D printing in the scope of their service provision. The keywords of papers were also investigated, considering their frequency (Figure 5).

Among 44 terms, the most recurrent were "3D Printing", appearing nine (9) times, "Additive Manufacturing" three

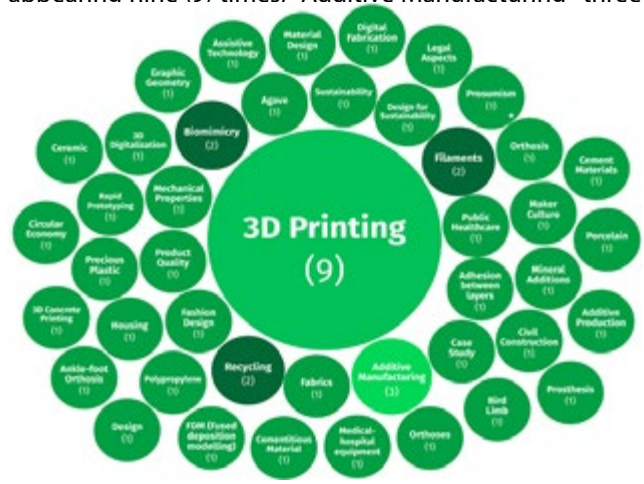

Figure 5: Keywords of studies.

Source: Authors (2023).

(3), "Biomimetics", "Filaments" and "Recycling" two (2) each. There are only one (1): "3D Concrete Printing", "3D Digitization", "Additive Manufacturing", "Adhesion Between Layers", "Agave", "Ankle-Foot Orthosis", "Assistive Technology", "Bird Limb", "Case Study", "Cementitious Material", "Cementitious Materials", "Ceramics", "Circular Economy", "Civil Construction", "Design", "Design for Sustainability", "Digital Manufacturing", "Fabrics", "Fashion Design", "FDM (Fused Deposition Modelling)", "Graphic Geometry", "Housing", "Legal Aspects", "Maker Culture", "Material Design", "Mechanical Properties", "Medical-hospital Equipment", "Mineral Additions", "Ortheses", "Orthesis", "Polypropylene", "Porcelain", "Precious Plastic", "Product Quality", "Prosthetics", "Prosumism", "Public Healthcare", "Rapid Prototyping" and "Sustainability".

Finally, it was found out what studies resulted in/focused

Data Base	Publications year	Title	Authors	Central theme(s)
ENSUS	2019	Prótese de membros em pássaros: estudo de caso de aplicação da Biomimética e impressão 3D	Rayane França Paes Queiroz, Cynara Fiedler Bremer e Fernando José da Silva	Product-Service System (PSS)
		Da Representação Gráfica 3D à Fabricação Aditiva de Cerâmicos Industriais de Forma Complexa	José Manuel C. B. C. Frade e Josiane Wanderlinde Vieira	Ecodesign
	2020	Uma Revisão Sistemática da Literatura sobre os Processos de Design direcionados a Manufatura Aditiva em Fab Labs para melhoria da qualidade do produto e redução de resíduos	José Ignacio Sánchez e Germannya D`Garcia Araújo Silva	Ecodesign + Waste Reduction
	2021	Utilização de cinza volante (CV) para impressão 3D	Lívia Fernanda Silva, Gustavo de Pinho Tavares Filla, Ester Meira Ramos Amorim, Monique de Brito Filgueiras e Berenice Martins Toralles	Waste Reduction
		Elementos de concretos produzidos por impressão 3D com foco na aderência entre camadas: uma revisão	Monique de Brito Filgueiras, Lívia Fernanda Silva e Berenice Martins Toralles	Waste Reduction
	2022	Digitalização 3D e impressão 3D de baixo custo voltada à saúde pública: estudo de aplicação em órtese infantil	Leonardo Teixeira Bortoleto e Claudio Pereira de Sampaio	Product-Service System (PSS)
ENSUS	2023	Desenvolvimento de Órtese Pediátrica do Tipo Tornozelo-Pé com uso de Impressão 3D	Herbert Renato Coelho Gomes, Cláudio Pereira de Sampaio, Sônia Maria Fabris e José Antonio Vicentin	Product-Service System (PSS)
		Pesquisa, Desenvolvimento & Fabricação Digital com uso da Impressão 3D: desafios para o desenvolvimento e regulamentação de dispositivos na área da saúde	Sonia Maria Fabris Luiz, José Antônio Vicentin e Cláudio Pereira de Sampaio	Product-Service System (PSS)
		Sustentabilidade e materiais: Viabilidade da produção de filamentos para impressão 3D através da utilização de polipropileno reciclado	Tauana Batistella e André Canal Marques	Recycling
MIX SUSTENTÁVEL	2019	Investigação de Estratégias de Leveza e Resistência das Fibras de Agave para Material de Impressão 3D Bioinspirado	Amilton José Vieira de Arruda, Emília Cristina Pereira Arruda e Rodrigo Barbosa de Araújo	Ecodesign
	2021	Estudo da Viabilidade de Fabricação de Filamento Compósito Sustentável para Impressão 3D a partir de uma Matriz PLA Reforçada com Resíduos de Fibras de Madeira	Daniel Lauxen Spohr, Felipe Antônio Lucca Sánchez e André Canal Marques	Recycling
		Design e Impressão 3D na Pandemia: Uma Análise de Possibilidades a partir do Modelo Teórico DFSS	Cláudio Pereira de Sampaio e Sonia Maria Fabris Luiz	Product-Service System (PSS)
	2023	Impressão 3D com Materiais Cimentícios: Uma Análise Comparativa de Projetos Residenciais	Luana Toralles Carbonari, Berenice Martins Toralles, Lívia Fernanda Silva, Lisiane Ilha Librelotto e Thalita Gorban Ferreira Giglio	Sustainable Development
P&D DESIGN	2018	Tecido Impresso em 3D para a Indústria do Vestuário	Lais Estefani Hornburg, Carine Rorato de Oliveira, Arlete Ehlert de Souza, Jeferson Daronch e Danilo Corrêa Silva	Ecodesign
	2022	A impressão de Artefatos 3D como Alavanca Social: o 3DP e o movimento maker no contexto pernambucano	Luiz Valdo A. Maciel, Amilton Arruda e Thamyres Clementino Oliveira	Sustainable Development
SIMPÓSIO DE DESIGN SUSTENTÁVEL	2019	Plástico Precioso: prototipagem rápida e reciclagem de resíduos de manufatura aditiva	Mario Ruiz Manrique, Leticia Teixeira Mendes, Auta Luciana Laurentino e Sadi da Silva Seabra Filho	Recycling

CHART 1: Systematic Bibliographic Review Detailing

Source: Authors (2023).

on, whether product or service (Figure 6).

Figure 6: Result/focus of studies.

Source: Authors (2023).

It was found that of sixteen (16) studies, fourteen (14) resulted in or focused on product, only one (1) on service and another (1) about the union of product and service. The only study focused on service is "A impressão de Artefatos 3D como Alavanca Social: o 3DP e o movimento maker no contexto pernambucano", by Luiz Valdo A. Maciel, Amilton Arruda and Thamyres Clementino Oliveira, and on product + service: "Design e Impressão 3D na Pandemia: Uma Análise de Possibilidades a partir do Modelo Teórico DFSS", by Cláudio Pereira de Sampaio and Sonia Maria Fabris Luiz.

Based on the cases presented in analyzed studies, some guidelines are proposed for the application of Additive Manufacturing/3D Printing in sustainable projects/businesses, mainly taking into account environmental dimension (**Chart 2**).

CHART 2: Guidelines for Additive Manufacturing/3D Printing Sustainable

How to use Additive Manufacturing/3D Printing in a sustainable way?
1. Give preference to printing in Fab Labs/Digital Manufacturing Laboratories.
2. Use sustainable [biodegradable or recycled] filaments/liquid resins.
3. Adjust print settings appropriately to avoid wasting material and save energy.
4. Develop products with a minimum of components.
5. Offer replacement parts.
6. Pay attention to expiration date of liquid resins to avoid unnecessary disposal.
7. Enable disused/damaged products collection for recycling.
8. Adopt recycling techniques for leftover materials and discarded products.
9. Correctly dispose of unusable liquid resins, preferably at collection points.

Source: Authors (2023).

4. FINAL CONSIDERATIONS

Through the Systematic Bibliographical Review (RBS) carried out, a relevant overview was obtained to understand, and at the same time demonstrate, how Additive Manufacturing/3D Printing is capable of being used for sustainability. It was found that Product-Service System, Ecodesign, Recycling and Waste Reduction were prominent themes and that focus on products is greater in relation to services, taking into account that results prioritized tangible goods.

Other points to highlight are areas variety, such as design, architecture, health, fashion, which include sustainable projects with technology mentioned, and that data obtained highlights gaps to be filled, such as deficit of initiatives based on sustainable development and those that essentially result in service, in addition to low annual scientific production on subjects reviewed, and can contribute as guidelines.

Given this, it can be stated that initial objective, verifying how two areas that supported this review are related, was achieved, taking into account detailing studies scientific selected and information extracted from them.

The main difficulties involved accessing studies in databases whose annals are divided into several platforms and, in some cases, characterizing papers central themes.

For future study, it is suggested that RBS be carried out at other events and periodicals, including outside the Brazilian context, aiming for greater understanding and coverage, and possible updates to proposed guidelines.

REFERENCES

BRANDSTOTTER, M., HABERL, M., KNOTH, R., KOPACEK, B., KOPACEK, P. IT on demand - towards an environmental conscious service system for Vienna (AT). In: Proceedings of EcoDesign'03: Third International Symposium on Environmentally Conscious Design and inverse Manufacturing, 2003, Japão. **Anais**… Japão: 2003, p. 799-802.

CARVALHO, Jonas de; VOLPATO, Neri. Introdução à manufatura aditiva ou impressão 3D. In: **Manufatura aditiva**: tecnologias e aplicações da impressão 3D. São Paulo: Blucher, 2017.

CRESWELL, John Ward. **Projeto de pesquisa**: métodos qualitativo, quantitativo e misto. 3. ed. Porto Alegre: Artmed, 2010.

ERICKSON, Christine. **9 ways 3D printing can change the world**. Mashable, 26 fev. 2012. Disponível em: https://bit.ly/36gwT3f. Acesso em: 15 mai. 2023.

FIGUEIREDO, Elisabeth de Almeida; NASCIMENTO, Lucio Fabio Cassiano. Resíduos sólidos e a responsabilidade ambiental / Solid waste and environmental responsibility. **Brazilian Journal Of Development, Curitiba**, v. 7, n. 12, p. 114642-114659, 29 dez. 2021. South Florida Publishing LLC. http://dx.doi.org/10.34117/bjdv7n12-301.

GIL, Antonio Carlos. **Métodos e Técnicas de Pesquisa Social**. 6. ed. São Paulo: Editora Atlas, 2008.

LONJON, Capucine. **The history of 3d printer: from rapid prototyping to additive fabrication**. Sculpteo, 1 mar. 2017. Disponível em: https://bit.ly/2XdHhER. Acesso em: 05 mai. 2023.

MANZINI, Ezio. **Design para a inovação social e sustentabilidade**: comunidades criativas, organizações colaborativas e novas redes projetuais. Caderno do Grupo de Altos Estudos. Programa de Engenharia de Produção da Coppe/UFRJ. Rio de Janeiro: E-papers Serviços Editoriais Ltda, v. 1, 2008.

MANZINI, Ezio; VEZZOLI, Carlo. **O desenvolvimento de produtos sustentáveis**: os requisitos ambientais dos produtos industriais. São Paulo: EDUSP, 2002. 366 p.

MENEZES, Monica D.; VILAÇA, Paula C.; REIS, Luciana P. Technology roadmapping (TRM) no contexto do ecodesign: um estudo de caso da madeira plástica. In: XXX Encontro Nacional de Engenharia de Produção, 2010, São Paulo. **Anais**… São Paulo: ABEPRO, 2010, p. 1-13.

MORANDINI, Moisés Miranda; DEL VECHIO, Gustavo Henrique. IMPRESSÃO 3D, TIPOS E POSSIBILIDADES: uma revisão de suas características, processos, usos e tendências. **Revista Interface Tecnológica**, Taquaritinga, v. 17, n. 2, p. 67-77, 18 dez. 2020.

MOUSAPOUR, Mehrdad. **Multi-metal 3D printing with extrusion method**. 2020. 105 p. Dissertação (Mestrado) – Degree program Chemical, Biochemical and Materials Engineering, School of Engineering, Aalto University, Espoo, 2020.

ORGANIZAÇÃO DAS NAÇÕES UNIDAS (ONU). **Os Objetivos de Desenvolvimento Sustentável no Brasil**. 2015. Disponível em: https://brasil.un.org/pt-br. Acesso em: 28 jun. 2023.

PAZMINO, Ana Verónica. **Uma reflexão sobre Design Social, Eco Design e Design Sustentável**. Curitiba: I Simpósio Brasileiro de Design Sustentável, 2007.

PLATCHECK, Elizabeth Regina. **Design Industrial**: metodologia de ecodesign para o desenvolvimento de produtos sustentáveis. São Paulo: Atlas, 2012.

POZZETTI, Valmir César; CALDAS, Jeferson Nepumuceno. O descarte de resíduos sólidos no âmago da sustentabilidade. **Revista de Direito Econômico e Socioambiental**, Curitiba, v. 10, n. 1, p. 183-205, jan./abr. 2019. doi: 10.7213/rev.dir.econ.soc.v10i1.24021.

RIBEIRO, Helena; BESEN, Gina Rizpah. Panorama da coleta seletiva no Brasil – desafios e perspectivas a partir de 3 estudos de caso. **Revista InterfacHES**, n. 4. 2007.

RIUL, Marília.; SILVA, Lilian Ferreira Cardoso da; RIBEIRO, Edson Leite. Aspectos e Impactos Sociais e Ambientais da Indústria Moveleira e Experiências de Gestão. **Revista Principia - Divulgação Científica e Tecnológica do IFPB**, João Pessoa, n. 18, 2011. p.79-95.

SAMPAIO, Cláudio P. de; SANTOS, Aguinaldo dos; LOPES, Camila S. D.; TREIN, Fabiano A.; CHAVES, Liliane L.; LIBRELOTTO, Lisiane L.; FERROLI, Paulo Cesar M.; LEPRE, Priscilla R.; ENGLER, Rita C.; MARTINS, Suzana B.; NUNES, Viviane G. A. **Design para a sustentabilidade**: dimensão ambiental. Curitiba: Insight, 2018.

SAMPIERI, Roberto H.; COLLADO, Carlos F.; LUCIO, María del P. B. **Metodologia de pesquisa**. 5. ed. Porto Alegre: Penso, 2013.

SANTOS, Aguinaldo dos. **Seleção do Método de Pesquisa**: Guia para pós-graduandos em design e áreas afins. Curitiba: Insight, 2018. 228 p.

TUKKER, Arnold. Eight types of product-service system: eight ways to sustainability? Expiences from Suspronet. **Business Strategy and the Environment**. v.13, p. 246–260, 2004.

VEZZOLI, Carlo; KOHTALA, Cindy; SRINIVASA, Amrit; DIEHL, J.C; FUSAKUL, Sompit Moi; XIN, Liu; SATEESH, Deepta; SANTOS, Aguinaldo dos; CHAVES, Liliane Iten; CASTILLO, Leonardo A. G.; GÓMEZ, Carla. R. P.; NUNES, Viviane G. A.; LEPRE, Priscilla R.; ENGLER, Rita C.; MARTINS, Suzana B.

Sistema Produto + Serviço Sustentável: fundamentos. Curitiba: Insight, 2018. 196 p.

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