GUIDELINES FROM LITERATURE TO PRACTICE: FIRST KEY TO IMPLEMENT ECO-INNOVATION IN AN INNOVATION LABORATORY

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ABSTRACT

Today, eco-innovation is a major challenge for companies. This new innovation approach requires to renew current practices to meet new societal and environmental issues. To do this, more and more companies create innovation laboratories to support them in this process, by providing different tools and methods adapted to their needs. To integrate eco-innovation in these new spaces, tools must answer to differents criteria. The only tool proposed by the literature is the guidelines tool but by confronting it with current practices, limits of this tool and of the innovation laboratory practices were defined. In this paper we will question and deconstruct guidelines tool in order to propose a new vision of it through identification of eco-innovation attributes.

Keywords: Ecodesign, Guidelines, Innovation laboratory, Creativity, Design methods

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1 INTRODUCTION

Since several years, innovation is based on three main levers: price, technology, and usage (Wise, 2006). Price-driven innovation aims to reduce costs. Technology-driven innovation focuses on improving the performance of a product at the technological level. Use-centered innovation aims to satisfy the expectations and needs of the users of the proposed solutions.

To meet these demands, companies are "*seeking to renew their innovation and creation methods*" (Merindol et al., 2016). New practices and new tools are deployed in an industrial context (Baregheh, Rowley and Sambrook, 2009). One of the proposed tools is the implementation of new spaces, dedicated to innovation, inspired by the maker movement such as Fablabs, Living labs, Hackerspaces, Makerspaces (Bosqué, 2016; Merindol et al., 2016),... These new spaces represent a place and an approach supported by various actors, to renew the methods of innovation and creation through the implementation of collaborative and iterative processes, open and giving physical or virtual materialization (Merindol et al., 2016). Their objectives are to put usages back at the center of innovation processes, to focus the process on the user and his needs, to give new life to the exploration and innovation processes of companies, to revalue practical skills and to adapt to a context of deindustrialization (Merindol et al., 2016; Laborde, 2017). To achieve these objectives, these innovation laboratories are built on three main pillars: a specific place characterized by a particular architecture, arrangement and setting that influence the behaviour of the occupants (Russell and Ward, 1982); a team composed of various and heterogeneous actors such as researchers, engineers as well as experts in creativity and prototyping methods and tools (Duarte et al., 2019); and finally, methods to facilitate and support the coordination of creative ideas and group work (Magadley and Birdi, 2009).

However, recently, eco-innovation which consists of innovating by considering the environmental impacts throughout the life cycle of a product (Fussler and James, 1996; Kemp and Pearson, 2008; Teulon, 2015), is also considered as a lever for innovation (Metz et al., 2016).

The objective of this article is to find out how eco-innovation can be integrated in innovation laboratories through specific tools and methods. First, a state of the art of available eco-innovation and eco-design tools will allow to highlight that eco-innovation tools are mainly based on the evaluation of the environmental impacts of the final products, except guidelines tool. Then, a first experimentation will demonstrate that the guidelines are not implementable in creativity sessions in their actual form and will also identify a limit of the current practices in innovation laboratory, in the case of convergent activities. A second experimentation will propose a reworking of this tool to extract some attributes to define eco-innovation. To conclude, several ways to use this reworking will be proposed in a discussion.

2 STATE OF THE ART

80% of the environmental impact of a product, service or system is determined at the design stage (Wenzel, Hauschild and Alting, 1997). So, to answer the challenges of sustainable innovation, a solution can be the implementation of an eco-design approach. According to the Standard NFX30-264 Environmental Management - Support for the implementation of an eco-design approach (AFNOR, 2013), an eco-design approach sustains the "*systematic integration of environmental aspects from the design and development of products (goods and services, systems) with the objective of reducing negative environmental impacts throughout their life cycle with equivalent or superior service provided*". This approach from the beginning of a design process aims to find the best balance between environmental, social, technical, and economic requirements in the design and development of products. Many methodological approaches have been proposed to help designers take the environment into account. The objective of this paper is to propose a method that can be used from the ideation phase of the product design process and that can be implemented in an innovation laboratory. For this, several criteria are required:

- To be understandable easily and rapidly by non-expert (Cook, Metcalf and Bailey, 2005; Briggs and Reinig, 2007): the user doesn't have to be trained or aware of the environmental issues to be able to use the tool.
- To be usable during the ideation step (Shneiderman, 2002): the tool must be usable when we don't have a product yet, but to answer a problematic and help during the generation of ideas,

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- To involve specific characteristics (Sternberg, 1999; Hewett, Czerwinski and Terry, 2005). In this case, to provide eco-design levers: like the users can be not aware of environmental issues, the need to have a tool that give them some recommendations to support them and guide them in this approach.

A first step was to conduct a state of the art of existing eco-design tools to assess if they meet these criteria.

A lot of eco-design tools exists. In (Rousseaux et al., 2017), 652 eco-design tools are identified and studied. In this state of the art, four categories of tools illustrated by several examples will be studied: Life Cycle Assessment, matrix approaches, eco-profile, and ideation tools.

2.1 Life Cycle Assessment (LCA)

For this category, we will detail two specific tools. We will start with the standardized full Life Cycle Assessment and its simplified version. Afterwards a similar tool, derived from the first two, the EDIP tool.

- LCA and simplified LCA:

Life cycle assessment, the only normalized eco-design tool, is defined as the "*compilation and evaluation of the inputs, outputs and potential environmental impacts of a product system during all its life cycle*" (AFNOR, 2006). Its implementation in the innovation or design process is very complex (Garcia, 2015). This is particularly true in the early stages of the process, where it is often impossible to implement (Guilloux, 2009). To make its integration easier, a simplified life cycle assessment exists which considers only a part of the life cycle or only one environmental impact.

- EDIP Tool

The EDIP tool - Environmental Design of Industrial Products - is a tool developed over a period of 5 years that assesses the environmental impacts of a product over its entire life cycle (Wenzel, Hauschild and Alting, 1997). This tool differs from traditional LCAs by proposing its own method for assessing toxicity. It also proposes two additional steps in its approach: sensitivity analysis and the decision support. During these two steps essentials parameters and their uncertainty are identifying and supports to the different types of decisions to be taken during product development are providing (Wenzel and Alting, 1999).

In industry, the most LCA tools implemented are GaBi and SimaPro (Herrmann and Moltesen, 2015), but these tools, like the EDIP tool, and all LCA tools (simplified or not) require to be skilled to use them (Rossi, Germani and Zamagni, 2016). However, as Guilloux underlined in 2009 (Guilloux, 2009), these eco-design methodologies require to start from an existing product, whose life cycle is known, to carry out a study on each stage of the life cycle. The objective of these tools is to quantify the environmental impact of a product and identify its strengths and weaknesses (Tyl, 2011). It doesn't give recommendation to improve it, except for EDIP which provides eco-design levers to the user to improve the product design.

2.2 Matrix approaches

Matrix approaches allow to qualitatively evaluate products according to the environmental impacts of the selected life cycle stages. Two recognized approaches will be detailed: the MET matrix and the ESQCV approach.

- MET Matrix

This tool is a 3x3 matrix which aims to assess the most important environmental aspects of a product with minimum efforts (Brezet and Van Hemel, 1997). The impacts are divided between three categories, Material cycle, Energy use, and Toxic emissions (MET) and are evaluated for three main steps of the life cycle (production, use and disposal).

- Approach ESQCV

This approach consists of a qualitative assessment of the environmental problems that may be present throughout the life cycle of the product (AFNOR, 1998). The evaluation of each step of the life cycle combined with the three impacts evaluated (pollution and waste; depletion of natural resources; noise,

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odor, aesthetic damage) results in a qualitative assessment, of the type "very favourable" / "favourable"/ "unfavourable" / “no object” / “lack of data”.
These tools quickly evaluate some ideas during a creativity session (Bovea and Pérez-Belis, 2012). But to do that, it is required to have some knowledge on environmental impacts.

2.3 Eco-profile

Eco-profile tools provide an overview of the impacts of a product in a qualitative and/or quantitative way. These profiles can take the form of a questionnaire like a checklist or a diagram like the Eco-Compass and the LiDS Wheel.

- Checklists

Another family of eco-design tools identified are checklists. A series of specific questions for each phase of the life cycle of a product allows to establish its environmental profile by evaluating in a qualitative way if the product is environmentally friendly (Bovea and Pérez-Belis, 2012; Bellini and Janin, 2019). Industry can create their own checklists, it’s important for them to have specific tools that are adapted to their products and processes (Vezzoli and Sciama, 2006).

- Eco-Compass / LiDS

Eco-compass (Fussler and James, 1996) and the LiDS Wheel (Brezet, 1997) are two similar tools. They allow designers to quickly establish the eco-profile of their product in the form of an evaluation diagram. The product is evaluated around, respectively, five and eight eco-design axes from the different steps of the life cycle like “reduction of materials usage”, “energy intensity” or “reuse and revalorization”. Behind each axis, you have a list of recommendations to improve the product evaluated.

These tools are built on questions and suggestions usable to solve problems during the first step of design phases (Rossi, Germani and Zamagni, 2016). But, users need to be already trained or aware of environmental issues if they want to use it at its full potential (Cluzel, 2011; AFNOR, 2013).

2.4 Ideation tools

Ideation tools are tools that will allow the designers to generate ideas, or to categorize already developed ideas, during the creativity phases. Three of these tools will be detailed: EcoASIT, guidelines and PIT diagram.

- EcoASIT

EcoASIT is a method that consist in developing simulation phases to generate concepts that respond to a sustainable development logic (Tyl, 2011). It consists of three main steps. First, the objective establishment. It is articulated around the tool of nine screens (O’Hare, 2010) allowing to bring a global vision of the product, its components, and its environment and an evaluation of a reference product. Second, an idea generation phase. It based on three distinct creativity levers: eliminate, integrate, and modify. And to finish an evaluation phase, where the generated ideas are evaluated according to four defined criteria: originality, feasibility, environmental relevance, and potential influence on the socio-cultural context.

- Guidelines

Guidelines, or EcoDesign Principles (EDPs) are list of recommendations categorized according to the life cycle stages. They have been developed to support designers in the early development stages and consolidate best practices for enhancing the environmental performance of products (Maccioni, Borgianni and Pigosso, 2019). The guidelines take the form of recommendations such as: “use standardized components”, “facilitate maintenance” or “realize modular product”.

- Diagram PIT

The PIT diagram is a method for clustering eco-innovation ideas clearly (Jones, Stanton and Harrison, 2001). It structures ideas output from a creativity session by mapping them with the combination of some key-starting points for eco-innovation, a hierarchical structure for ideas from the main lever to the most concrete idea.

All these tools are made for the ideation step of the design process and are usable by non-experts of eco-design. EcoAsit gives three main creative levers but not clearly identified as eco-design levers. Diagram PIT can be considered like an organizational tool, it doesn't give eco-design levers, but allows to classify ideas generated during the ideation step.
The only tool answering to all our criteria are guidelines.

2.5 Tools comparison

This state of the art of the eco-design tools offers an overview of all the tools according to the criteria for implementation in an innovation laboratory (Table 1).

Table 1 : Comparison of eco-design tools according to the criteria of implementation in an innovation laboratory

Tools category	Examples	Understandable by non-expert	Usable during ideation step	Provide eco-design levers
Life Cycle Assessment (LCA)	LCA	No	No	No
	Simplified LCA	No	No	No
	EDIP Tool	No	No	Yes
Matrix approaches	MET Matrix	No	Yes	No
	Approach ESQCV	No	Yes	No
Eco-profile	Checklists	No	Yes	Yes
	Eco-compass / LiDS	No	Yes	Yes
Ideation tools	EcoASIT	Yes	Yes	No
	PIT diagram	Yes	Yes	No
	Guidelines	Yes	Yes	Yes

This state of the art highlights a wide variety of eco-design tools. However, despite this variety, it remains difficult to implement them in an industrial context because of different limits (Rossi, Germani and Zamagni, 2016): their complexity (Bovea and Pérez-Belis, 2012) ; the need for specific knowledge (Ritzén, 2000) and the time effort required by the user (van Hemel and Cramer, 2002).

Guidelines are identified as the only tool that corresponds to all the criteria proposed: be understandable by non-expert, be usable during the creativity phase and provide eco-design levers. Consequently, this is the only tool identified that can be implemented in an innovation laboratory.

3 METHODOLOGIES

3.1 First experimentation: Guidelines and industrial innovation laboratory

In the state of the art, guidelines tool was identified as an ecodesign tool usable in an innovation laboratory. The objective of this first experimentation is to develop a unique list of recommendations based on various guidelines found in the literature. This list should be implemented in an industrial innovation laboratory in order to improve its practices. Inspired by the innovative places, some companies have developed industrial innovation laboratories. These labs combine the spirit of the open lab with industrial constraints in terms of competitiveness, industrial properties, etc.

In the literature, many lists exist. They can be oriented on life cycle, circular economy, users.... They are written in many languages and come from books, articles, standards. Among all these lists, seven lists, representative of the heterogeneity of the literature, are selected. For this experiment, the following lists are kept:

- A guideline from Teulon (Teulon, 2015) composed of 56 recommendations ;
- A guideline from the standard (AFNOR, 2002) with 36 recommendations ;
- A list written by (Maccioni, Borgianni and Pigosso, 2019) with 66 recommendations ;
- A guideline of (Brezet and Van Hemel, 1997) divided into 33 recommendations ;

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- A list oriented circular economy written by (Bovea and Pérez-Belis, 2018) and composed of 46 recommendations ;
- A guideline written by (Issa et al., 2015) composed of 39 recommendations ;
- And a last list from (Van Hemel, 1998) with 33 recommendations.

For this experimentation, the usual practices of innovation laboratories are followed by organizing a creativity session and using collective intelligence. To participate to this session, a team with a representative level of eco-design knowledge was formed. The team was composed of an expert in eco-design, two people who are sensitive to eco-design due to their professional and academic backgrounds, and three non-experts. To create this unique list, they had at their disposal different tools to be able to "manipulate" the guidelines, cut them, assemble them, and play with them.

During the activity, the subjective nature of these lists of guidelines was quickly observed. The participants, having different understandings of the guidelines, quickly opted to do the work individually and not in groups as initially planned.
Many verbatims were collected:

- *"What is a cascade approach?"*
- *"What do they mean by 'active disassembly'?"*
- *"What is the final product?"*
- *"We agree that all these recommendations don't relate to the environmental impact of the product"*
- *"Not all recommendations are clear"*
- *"There are some things that are obvious and others that are not so"*
- *“Do you have some examples to illustrate them?”*

They show that the guidelines are not understandable easily and rapidly by non-expert users and as an individual's cognitive ability declines over time (Briggs and Reinig, 2007), creativity tools must be simple to understand.

At the end, the initial objective of developing a unique list of recommendations was not achieved. However, this experimentation highlighted two important results:

- A guidelines tool cannot be used in creativity session as it is now. Three different issues on the tool were highlighted: the subjective aspect, the complexity of understanding by non-experts and the lack of visualization. Some notions proposed are sometimes specific to the field of eco-design, such as "cascade approach" or "systemic thinking". Moreover, even if the tool gives recommendations to designers and potential participants of the creativity sessions, these recommendations is lacking visualization: examples were requested many times during the experimentation.
- The usual practices of innovation laboratories did not allow to answer the initial objective. Indeed, the practices of innovation laboratories propose divergence and convergence activities. This experimentation proposed only the convergence activity by aiming to create a unique list of recommendations. The limit of the current practices identified is the use of creativity sessions (activity in group) in the case of extremely convergent objectives. An individual activity will be more appropriate.

3.2 Second experimentation: identification of eco-innovation attributes

With the concluding remarks of this first experimentation, a new question was raised: how to adapt the guidelines to use them in a creativity session of an innovation lab?
It was highlighted that due to the difficulty of understanding them by non-experts in eco-innovation, the guidelines in their current state cannot be implemented in an innovation laboratory. The objective of this second experimentation was to simplify the guidelines to make them understandable by all. To do so, a semantic analysis of the seven lists previously selected was performed to identify the

attributes of eco-design. To conduct this analysis, the following methodology was adopted (Baregheh, Rowley and Sambrook, 2009):

- Counting of words frequencies
- The number of times words appear in all guideline lists
- The number of lists the word appear
- Grouping of words with the same stem (e.g., recyclable, recyclability, and recycle) in the word frequency results
- Clustering antagonist words (increase and decrease for example) which are the same lever in creativity
- Ponderation of the apparition of the different words, by multiplying the number of times the word appeared in the seven lists and the number of lists where this same word appeared. This scoring allowed us to give a score in percentage of importance of the word.
- To compare the importance of the words in the guidelines, by transforming the ponderation in a percentage,
- Elimination of the group of words, which appeared only a few time
- Identification of the eco-innovation attributes

4 RESULTS

The semantic analysis highlighted a total of 51 words. After grouping the words in the same family and the antagonists, then deleting the groups of words with a low percentage (less than one percent), a total of 26 groups of words are identified. These words groups which represent the main results of the second experimentation are divided into two categories: verbs, consisting of 10 words groups, and nouns, consisting of 16 words groups (with nouns or adjectives). The results of this experimentation are presented in a table (Table 2 and Table 3). First column displays the words counted. In the next two columns show the number of iterations of this word, i.e., the number of times the word appears in the recommendations, followed by the number of lists in which the word appears. The third column was used to put a weight to each of these words by multiplying the first two values. And the last column shows the percentage of word appearances in relation to their total weight.

This semantic analysis highlighted the fact that despite the multiplicity of guidelines (in this case, seven lists studied representing more than 300 recommendations), common attributes can define eco-innovation. The results may differ according to the lists studied and a larger number of lists would allow to have a more refined result, but the seven lists studied are considered as sufficiently representative and heterogeneous for the desired result. With these only seven lists, we have already a high redundancy of words and several which appeared like attributes of eco-innovation.

Table 2 : Analysis of the attributes in the guidelines lists (verbs)

Verbs				
	Number of iterations (i)	Number of lists where the word appeared (l)	Ponderation (i*l)	Percent of the total of ponderation
Minimize / Maximize Optimize	71	7	497	21%
Use / Usage / Utilization	70	7	490	21%
Reduce / Increase / Decrease / Limite	60	7	420	18%
Chose	55	6	330	14%
Facilitate	27	6	162	7%
Recycle	22	7	154	7%
Reuse / Repair	18	7	126	5%
Design	17	6	102	4%
Adapt / Modify	10	3	30	1%
Collect / Collection	4	3	12	1%

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Table 3 : Analysis of the attributes in the guidelines lists (nouns)

Nouns				
	Number of iterations (i)	Number of lists where the word appeared (l)	Ponderation (i*l)	Percent of the total of ponderation
Material / Resources	82	7	574	19%
Product	53	7	371	12%
Component / Packaging	39	7	273	9%
Energy	39	7	273	9%
Multifunction / Disassembly / Modular	24	7	168	6%
Consumption	25	6	150	5%
Maintenance	19	7	133	4%
Renewable / Safe /Hazardous	22	6	132	4%
Waste / Consumables	22	6	132	4%
Transport / Logistic	21	6	126	4%
Life span / Durability / End of life	21	6	126	4%
Weight / Volume	23	5	115	4%
Efficient / Reliable	18	6	108	4%
Impacts / Emissions	21	5	105	4%
Production	17	6	102	3%
Environment	10	5	50	2%

5 CONCLUSION

Innovation labs are renewing innovation practices in the industrial context by proposing specific methods and tools (Lallement, 2015; Anderson, 2017). Today, the emergence of a new innovation lever, environmental innovation, is challenging these places to adapt their practices, develop new tools, to answer this challenge.

A state of the art of the different eco-design tools existing showed that the tool that best meet the expected criteria is guidelines. These lists of recommendations are presented as understandable by non-experts in the field, usable in the creativity phase and giving recommendations by the literature.

After two experimentations conducted, different results were highlighted:

- The subjectivity and complexity of understanding guidelines and their lack of visualization and associated examples.

Unlike what can be found in the literature, guidelines tool is a less understandable tool than one might think. And don't complete the required criteria for creativity sessions.

- A limit of current innovation laboratories practices.

Creativity sessions are at the centre of these innovation spaces. However, the creativity session, although fruitful in identifying the barriers to the implementation of guidelines in a creativity session, did not succeed in the creation of a unique list. The first experimentation being very convergent, the collaborative work was not adapted. An individual activity was more appropriate.

- Attributes to define eco-design.

A semantic analysis was conducted to rebuild the guidelines, to think them differently, and so that they can meet the expected criteria. It identified attributes that can define eco-innovation, i.e., creativity levers for eco-innovation. This analysis was conducted only on seven lists due to the high number of existing lists (Issa and Pigosso, 2013; Go, Wahab and Hishamuddin, 2015).

The 26 attributes identified can be divided into two categories: nouns/adjectives (sixteen attributes) and verbs (ten attributes).

The attributes defined through this analysis will now allow to develop new tools for innovation labs and creativity sessions. They make it possible to develop creativity boosters to stimulate the creativity of sessions participants for example. The association of a word from the list of verbs and another one

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from the list of words will create acreativity lever for eco-innovation. Evaluation matrices, mood boards, or other tools can be imagined around these attributes.

The next objective is to build different tools according to the three criteria presented : be understandable easily and rapidly by non-expert (Cook, Metcalf and Bailey, 2005; Briggs and Reinig, 2007), be usable during the ideation step (Shneiderman, 2002) and involve specific characteristics (Sternberg, 1999; Hewett, Czerwinski and Terry, 2005) of eco-design levers according to the attributes define. And test them to identify which tools are the most relevant to implement in innovation laboratories practices to improve them in term of creativity and eco-innovation.

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