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# Proposal of an eco-design framework based on a design education perspective

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**Abstract**

In order to overspread a successful sustainable design of products and services, it is necessary to educate engineering designers at university and along life. Although literature already provides eco-design processes, frameworks, methods and tools, it does not seem to take into consideration the need for a progressive education to eco-design practice. This research proposes a framework based on six fundamental dimensions fractioned into multiple levels: Choice and management of criteria; Modeling of life cycles; Management of the eco-design process; Levels of calling into question of products and services; Integration of industrial stakeholders; Integration of civil stakeholders. The eco-design framework is finally illustrated through its usefulness in describing tools and supporting eco-design education trajectories.


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Keywords: eco-design; education; framework; levels

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## 1. Introduction

Environmental, and more broadly sustainability concerns have been important issues in the design of industrial products and services for the last two decades.

Education to sustainability is also acknowledged to be a key challenge to move towards a sustainable society (Manzini, 2009). In order to operate this move, eco-design knowledge and practices have to be integrated to education programs, and especially to product design curricula. The term 'eco-design' is defined from a normative point of view in the ISO/TR 14062 as an activity that integrates environmental aspects into product design and development (ISO, 2002). Commenting on the best practice of ISO/TR &4062, Lee & Park (2005) add that eco-design also integrates stakeholders requirements in the process. Eco-design can also be seen as "*one strategy being employed to move towards a more sustainable future*" (Bhamra, 2004).

The adoption of eco-design and sustainability principles requires to build "*a coherent approach to the field*" for students and professors (Pezeshki, Panchal & Ameta 2012). So far much effort in eco-design education has been made to develop: (1) simplified environmental assessment tools manageable by students (for instance EcoIndicator 99); (2) eco-design guides promoting a step-by-step approach, for instance the UNEP guide (Brezet & Van Hemel, 1997), the Environmental Improvement guide (Mc Aloone & Bey, 2009); the D4S (Design for Sustainability) guide (Crul & Diehl, 2009). There seems to be a lack of holistic view to embrace the wide spectrum of environmental issues. Those issues are indeed subjected to fast changes, opening up for


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instance to usages in the perspective of economic and societal impacts (Jolly, 2013).

The argument of this paper is to develop a framework suitable for eco-design education, enabling us to emphasize:

- the systemic dimension of eco-design practice,
- a transition towards sustainable design.

The research question tackled in this paper is : *"How to frame eco-design education in a sustainable perspective?"*. This paper is an attempt to unify and organize topics to build eco-design curricula in a meaningful way.

On that purpose, section 2 investigates existing frameworks and models related to eco-design implementation in industry, and in academia for education purposes. In section 3, the proposition of the eco-design framework is developed, emphasizing three important issues in eco-design knowledge: environmental stakes, stakeholders across life cycles and integration to the design process. This leads to a first applicative step in section 4. Finally a conclusion and perspectives of future work are provided in section 5.

## 2. Eco-design frameworks and models

The aim of this section is to present current frameworks or models dealing with environmental issues within product design, environmental management or knowledge management field. Our understanding of how to define an eco-design framework is in line with Smyth (2004): a research tool to help to develop awareness and communication on environmental issues. It is hence a general structure composed of a set of concepts, meaning to be representative of the way of viewing eco-design practice and processes in a sustainability perspective. On the other hand a model is supposed to be more specific, while emphasizing interrelated factors to be tested.

### *2.1. Frameworks and models for eco-design implementation in industry*

Various attempts have been made through academic works related to industrial projects to propose eco-design frameworks emphasizing various dimensions. In the domain of environmental management, DeWulf activates Environmental Performance Indicators (EPI) to manage eco-design across the stacked levels of the project (i.e. on the design team level), the company and the industry sector (DeWulf, 2003).

For Millet al. (2002), the contribution of knowledge management enables to propose a model of environmental knowledge creation based on three activities: formalization, diffusion and valorization of the environmental knowledge. The notion of step is associated with each activity, fractioned into three progression levels. For the valorization activity, the environmental dimension shifts from the status of a constraint, to a criterion, and finally to a real added value for the company.

Reyes & Rohmer (2009) are also concerned with the elaboration of a long-term framework for integration of the environment in industrial product design processes (in SMEs more specifically). Once again the objective is to settle a progressive scheme of integration based on a relational dimension (related to involved actors); an informational dimension; a methodological dimension (related to eco-design tools).

More recently, Pigosso, Rozenfled & Mc Aloone (2013) elaborated an eco-design maturity model based on a continuous improvement approach. Three elements are put forward by authors: (1) eco-design practices related to environmental management; (2) maturity levels combining evolution and capability levels of the company; (3) application method i.e. how to use the model. This proposition is positioned as an improvement of a process from a managerial perspective, as opposed to product improvement operated on a technical level. The strength of this work is to establish the current eco-design maturity profile of a company to pave the way for future practices and improvement projects.

### *2.2. Eco-design frameworks and models for education*

In the field of eco-design education, some recent research works are devoted to the development of eco-design or sustainability frameworks and models.

Blizzard & Klotz (2012) propose a holistic sustainability framework based on whole systems approach. The aim is to address the interrelated issues of sustainability. The three core elements of the framework are the following:

- Design processes defining how information should be shared in context of common vision and mutual learning;
- Design principles guiding towards the desired outcomes;
- Design methods including life cycle thinking and ecological strategies from a natural world.

Pezesheki, Panchal & Ameta (2012) distinguish four areas for their eco-design and sustainability model for higher education: (1) Core science; (2) Facilitative strategies, for instance tool development; (3) canonical eco-design philosophy, i.e. decision-making processes; (4) conceptual knowledge and paradigms shift.

Lockrey and Bissett Johnson established an interesting design and DfE (Design for Environment) curriculum for cross-disciplinary project students (Lockrey & Bissett Johnson, 2013). Being industry-based, the approach is also supported a so called 'educational scaffold', i.e. a reflective process mixing design and DfE, from concept to detail design.

In conclusion to this literature review, it is noticed that if the notions of maturity and levels in environmental awareness can be found in industry-focused eco-design research, this does not seem to instill into education-focused approaches.

The identified research issue is therefore to provide students and practitioners a comprehensive multi-level -but nonetheless operational- framework to support eco-design of products and services in the context of engineering design. The research methodology leading to the first version of the eco-design framework is presented in next section.

## 3. A framework for eco-design education

### *3.1. Research methodology*

The research method employed is literature-based and deductive. Therefore the conceptual proposition of the framework is built prior to the testing phase. The underlying hypothesis is that *'It is possible to frame eco-design education with an eco-design framework embedding several dimensions and levels (on each dimension)'*. In order to be usable and understandable, the framework should moreover have a limited number of dimensions, ideally between 3 and 5 to be storable by memory (Cowan, 2001).The work was carried out by two researchers. After extracting two dimensions from the definition of eco-design according to the ISO/TR 14062 (ISO, 2002), other relevant dimensions were identified through a literature review process. The resulting dimensions (Fig. 1) were clustered into three groups, as exposed in next sub-sections: core dimensions of eco-design; dimensions related to the design process; dimensions related to the value chain . In summary, the following steps were implemented.

(1) Identification of 2 dimensions (and associated levels) related to the concept of eco-design: life cycle; environmental impacts.

(2) Identification of 3 complementary dimensions through literature review: Levels of calling into question of products; Integration of stakeholders; Management of the eco-design process.

(3) Separation of the 'Stakeholder' dimension into two distinct (but nevertheless connected) dimensions for clarity: industrial and civil stakeholders.

This version of the framework was then evaluated by six practitioners and researchers responsible for eco-design curricula in French higher education. This was done through semi-structured interviews and e-mailed questionnaire with 28 open and closed-ended questions, enabling to fine-tune the proposed model.

The applicative part of the research encompasses two types of investigations: a test to characterize existing eco-design tools and toolboxes (4.1); the deployment of the framework to build a eco-design trajectories (4.2).

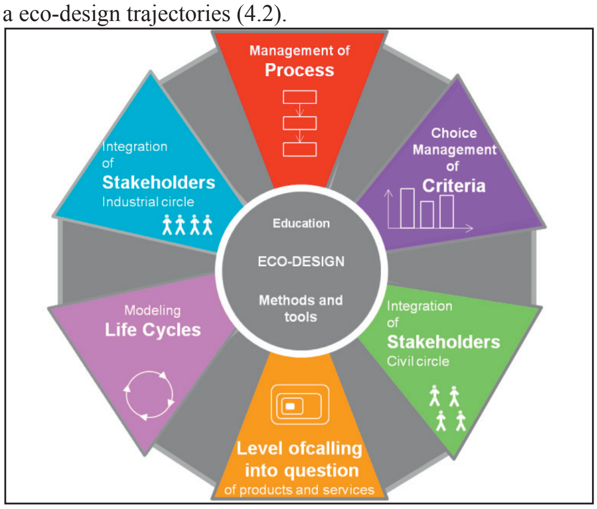


Fig. 1: Representation of the 6 core dimensions of the eco-design framework

### *3.2. Core dimensions of eco-design*

Just as eco-design, eco-design learning relies on two predominant aspects: considering multiple stages of the life cycle of products and multiple assessment criteria.

**Modeling life cycles**. Learning eco-design requires to consider the targeted life cycle stages to reduce the environmental impacts and increase the value to the customer and society. It is possible to focus on a partial cycle (from 'cradle to gate' or from 'gate to grave') or on an entire life cycle from 'cradle to grave'. When considering the remanufacturing of products, several usage cycles are taken into consideration as pointed out in Amaya et al. (2010). The authors propose a tool to compare remanufacturing scenarios for 1 to 3 usage cycles.

**Choice and management of environmental criteria**. Learning eco-design supposes to define relevant and understandable criteria to assess the environmental performance of products and services. The easiest way (but most restrictive) is to use one or several technical criteria, which are meaningful for designers: for instance mass or energy consumption (Dewulf, 2003). A deeper knowledge on local and global impacts allows to consider a larger sample of criteria, both technical and environmental (for instance Global Warming Potential or eutrophication indicators). If the knowledge is broadened to sustainability, criteria should also embed ethical and social values (cf. Gupta et al. (2011) regarding sustainable manufacturing). Lastly, a distinction in difficulty can be made between use of single-criterion and multiple criteria approaches for the first two levels.

### *3.3. Dimensions related to the value chain*

Eco-design learning not only focuses on the consideration of life-cycles of products and services, but should also raises awareness of learners on the fact that multiple stakeholders are tied together with each step of the life-cycle (Mc Aloone & Bey, 2009).

**Integration of industrial stakeholders.** Learning eco-design also relies on the awareness of the possible levels of commitment of companies to eco-design practices. This approach results from the contribution of organizational learning to eco-design defining the dynamics of integration of the environment into the industrial departments (Millet et al., 2003; Reyes, 2007). On a first level, the environmental expert is the only person in charge of environmental issues. On a second level, the design team collaborates with the environmental experts. The third level consists in the involvement of all the departments of the company as well as suppliers (i.e. the extended enterprise). On the last level, the environmental stakes are shared in a holistic manner by several companies of an industrial eco-system or symbiosis.

**Integration of civil stakeholders.** Learning eco-design requires to envisage the consideration and commitment of actors of the civil society in the development of eco-designed products and services. The basis of this dimension is the organization of the civil society as described in UNEP (1994). The first classic stakeholder to be considered is the final client or consumer, whose attitude towards sustainable usage is typically addressed in the 'Design for Sustainable Behavior' approach (Lilley, 2007). On the next level, the concerns of communities (for instance NGOs, mass media, local governments) have to be reported in the eco-design projects. The upper level deals with the institutional organizations. For instance, the EU is an implicit stakeholder for it governs the development of classes of products and services through the application of environmental directives.

### *3.4. Dimensions related to the eco-design process*

In order to eco-design products and services, practitioners have to master two different notions: the level of calling into question that is expected on a given project and the management of the eco-design process to achieve the task.

**Definition of levels of calling into question.** Learning to eco-design is about positioning about the envisaged levels of calling into questions of products and services on an environmental scale. According to Brezet (1997), four levels of progression can be distinguished: product improvement, product redesign, functional innovation; system innovation. Environmental improvement is devoted to make the product compliant with current environmental standards. Product redesign intends to modify certain features or components in isolation (for instance choice of materials) whereas functional innovation leads to an explicit change in technology or usage. Systemic innovation provides a portfolio of new products and services, implying in the meantime noticeable modification of infrastructures and organization of companies.

**Management of the eco-design process**
Learning eco-design requires to understand and practice a number of interconnected activities organized in an eco-design process. Each kind of activity is related to a family of eco-design tools. Major eco-design activities or steps are synchronized with the aims of a traditional product design process (Millet et al., 2003):

- Environmental diagnosis, including goal definition and initial environmental assessment;
- Environmental strategy: prioritization of the environmental issues;
- Environmental assessment and decision making.
- Solution finding: definition of ideas and environmentally friendly concepts;
- Environmental communication on benefits of the proposed solution(s).

### *3.5. Synthesis of the proposition*

A circular representation (i.e. a rosette-type figure) appears to be most the appropriate to communicate the multiplicity and complexity of environmental stakes in eco-design learning. Hence a coherent visual presentation of eco-design dimensions is created (Fig. 2.).

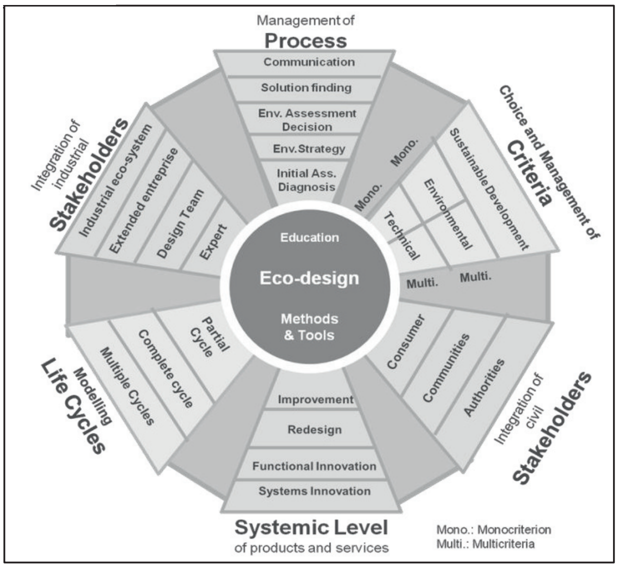


Fig. 2. Description of the eco-design framework.

## 4. Application of the eco-design framework

### *4.1. Description of eco-design tools*

In order to test the usability of the framework, a descriptive study of an approximate number of 30 existing and acknowledged eco-design tools was performed. The following questions concerning the core dimensions were adjusted:

- **Modeling life-cycles**: what are the stages of the life cycle, or what are the life cycles of products/services taken into account by the tool?
- **Choice and management of environmental criteria**: what are the evaluation criteria proposed by the tool?
- **Integration of industrial stakeholders**: what are the industrial stakeholders' viewpoints expressed through the tool?
- **Integration of civil stakeholders**: what are the civil stakeholders' viewpoints expressed through the tool?
- **Definition of levels of calling into question**: what level of calling into question of products/services is the tool meant to address?
- **Management of the eco-design process:** what are the stages of the eco-design process tackled by the tool?

The extensive survey of the entire set of tools is not developed here for brevity. By way of example, a detailed characterization of the EcoDesign PILOT tool (Wimmer & Züst, 2003) is detailed below (Table 1).

Table 1. Characterization of EcoDesign PILOT with the eco-design framework.

| **Eco-design tool** | **EcoDesign PILOT (EDP)** |
|---|---|
| Dimension | Comment |
| Life cycles | EDP relies on a full life cycle representation. |
| Criteria | Criteria used in EDP deal with mass, energy consumption and waste volume. These are technical criteria usually managed by design engineers. |

| | |
|---|---|
| Industrial Stakeholders | The implementation of EDP is well adapted in a design team facilitated by an environmental expert. |
| Civil Stakeholders | EDP does not sate to any specific viewpoint of civil stakeholders. |
| Levels of calling into question | EDP focuses on improvement of redesign of products. |
| Eco-design process | EDP was created to mainly help with : the definition of environmental strategies for the targeted application; solution finding through illustrated guidelines. |

Relying on the aforementioned questions, it is also presented how the eco-design framework can help analyze the rate of thematic coverage of an eco-design toolbox. It is stated that this rate is defined at two levels:

- at a global level thanks to the number of dimensions considered in the toolbox. It is thus expressed by a percentage GC between 0 and 1 (i.e. 6/6 dimensions);
- at a detailed level thanks to the number of levels considered for each single dimension. The detailed coverage (DC) represents the sum on total number of dimensions j of the independent levels $I_j$, out of the total number of levels (i.e.22).

$$DC = \sum_{j=1}^{6} Ij / Nj * 100$$

The Toolbox for Sustainable Design developed in Loughborough University is used as an illustration of the rate of coverage. This toolbox is composed of five qualitative and quantitative tools: the EcoDesign Web, the Design Abacus, the web guide Information Inspiration, EcoIndicator 99 for assessment and the material database from CES Edupack (Lofthouse, 2009).

On a general level, it appears that each dimension is tackled at least once by the tools, and possibly several times. The global rate GC equals 100%. For the Life Cycle dimension, every tool but Information Inspiration reflects on a 'full cycle' level. Hence DC on this level equals 1, i.e. one single level represented out of 3. Finally, the detailed coverage DC of the toolbox across all dimensions reaches 59% (i.e. 12/22). The main gap pointed out by this analysis concerns the poor representation of civil stakeholders through the toolbox, currently limited to the final user.

### 4.2. Support to trajectories in eco-design education

This last part deals with the practical question of how the eco-design framework should be used and taught. Three types of trajectories can be envisaged (Fig. 3).

- Area-by-area trajectory: eco-design learners may investigate in depth every dimension (or area) through various means of exploration (industrial projects, seminars for instance).
- Level-by-level trajectory: eco-design learners may gain understanding and practice on all dimensions or areas (almost) simultaneously. This implies a circular progression from a 'lower' level of difficulty (for instance redesign of products) to an upper level across the different areas.
- Cross-area trajectory: it is also possible to investigate meaningful topics resulting from the combination of different areas. For example one may combine the 'criteria' dimension with 'stakeholders' areas by questioning: "How is it possible to chose and manage relevant environmental/sustainable criteria depending on the stakeholders (industrial or civil) involved in the eco-design process?".

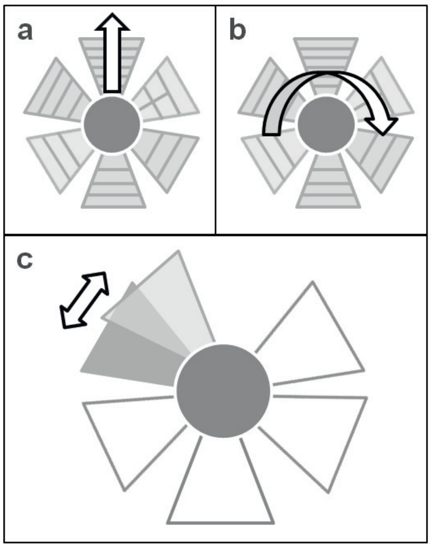


Fig. 3. (a) area by area trajectory; (b)level by level trajectory; (c) cross-area trajectory

## 5. Conclusion and future work

The aim of this paper was to define and develop a framework to frame eco-design education in a sustainable perspective. The literature review allowed to identify various framework and models using maturity and level concepts, and focusing on the eco-design process. The multiple viewpoints on eco-design expressed in literature conducted to a first version of the eco-design framework, which embraces six main dimensions: Choice and management of criteria; Modeling of life cycles; Management of the eco-design process; Levels of calling into question of products and services; Integration of industrial stakeholders; Integration of civil stakeholders. Each dimension is then fractioned into multiple levels. The applicability of the framework was demonstrated through two types descriptive works: characterization of eco-design tools; elaboration of progressive eco-design trajectories. This first investigation reveals that the proposition in its first version gives a large overview of the subject, seems manageable and useful.

In future work, an empirical insight to test the framework with students is needed. The proposition is being elaborated through a detailed description of eco-design activities associated with dimensions, levels and appropriate tools. Moreover, further evaluation from international experts is necessary to judge the usability and comprehensiveness of the framework.

As it is an updatable framework, it is possible to shift levels or add emerging dimensions depending on the evolution of the eco-design knowledge. Lastly, it is envisaged to use the framework in long life education or in industry to build eco-design/sustainability roadmaps.

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