Ecodesign: what to teach in specialised or generic engineering education

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Eco-design: what to teach in specialized/generic engineering education
What are the needs for entrepreneurship education?

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INTRODUCTION

We have now enough background in the teaching of eco-design to make some conclusions on practices and evolutions in this area; in France these teachings are very supported by studies of APEDEC (Association of Experts for the Development of Eco-Design) that published in 2006 and 2010 the results of enquiries concerning this subject.
Curricula concerning eco-design exist since 1987 but a significant number of graduates exist only since 1995, more often in engineering universities or design institutes. In 2009, the threshold of 3000 graduates in eco-design was gone over in France but only 20 curriculums could be considered as expert dedicated curriculum.
Now, even in engineering schools, we teach eco-design for services with a complementary view on usages in the perspective of economic and societal impact: the development of entrepreneurship education led engineering departments to evolve. The benefits of eco-design for the development of enterprises and the link between eco-design and innovation become a subject of course in engineering universities.
The paper tries to synthesize a description of those evolutions in the teaching of eco-design and present some typologies of curricula.

1 THE PREMICES IN THE TEACHING OF ECODESIGN

1.1 Birth of eco-design and of its teaching

Since the nineties [1], eco-design met an increasing interest, first in the research linked with enterprises and then, for the enterprises themselves because the degradation of environmental indexes and the development of regulations encouraged them to find solutions to their Sustainable Development problems.
The first approaches in the eighties were often only researches of improvement of technologies to satisfy the regulation. At this moment the teachings were realised inside the disciplinary teachings: textile, chemistry, intern combustion engines for

example, without a global consideration of the whole life cycle of the product and the term of eco-design was not yet used.
In the nineties, the approaches began to be more exploratory and concerned the great fields of sustainable development such as recyclability, waste reduction and applied research became involved, but very often only one criterion of pollution assessment and one step of the life cycle of the product were considered. The relation of eco design with teaching was the link that exists between research and education; that is to say that teachers who are also researchers spoke during their teachings about what they were doing to the students in the last year of master degree or during doctoral studies.
At the end of the nineties, the management of life cycle became the frame of eco-design; from this moment the introduction of eco-design in the engineering curricula became much easier to systematise; it is also the moment when sustainable development education became considered as something useful in the curricula and when the expected learning outcomes of courses began to include those linked to eco-design.

1.2 Development of eco design education

In 2006, according to APEDEC[2], curriculum including at least 20 hours on eco-design were 22 in France; 7 of them could be considered as expert dedicated curriculum, 9 as leading to an ability to realize an eco-design study and 6 as basic education courses.
The expert dedicated curricula had duration of 150 hours to 300 hours of teachings including case studies and a project needing about 100 hours of personal work. These courses had a good equilibrium between ecology and design.
Some engineering curricula made possible the choice of an option dedicated to eco-design of 30 to 60 hours with smaller projects. This option was very often a complement to the main domain of engineering
One or two day's curriculum (< 20 hours) was considered as only able to give an idea about the field of eco-design and to make students sensible to it. Very often, in this case, students had to present a small personal research on the subject. The students that followed such a curriculum were very enthusiastic.
At this moment, the strong link was between technological design and ecology: at the beginning, the first people to teach this subject were people making also researches in the field, often in link with material sciences (wood, textile, cars, and domestic use devices). In France there was a strong network called CREER which was basically composed of teachers belonging to engineering universities making researches in eco-design in the mechanical domain and of enterprises.
At the beginning, teachers of engineering schools dedicated much time to tools for environmental evaluation and eco-labels devoted to practical realization of LCA, very often with the use of the software considered as the reference in the domain of application. In many cases those teachings were mixed with teachings linked with de domain of application (mechanic, textile, chemistry, electronics...)

2 ECODESIGN BECOMES A STANDARD IN AN ENGINEERING COURSE

2.1 Eco-design has links with all steps of the job of the engineer

What appears on *Fig 1* is that eco design has links with many subjects of the education of engineers. So, two strategies are possible:

-make of it a specific subject including as well basic teachings on ecology as pluridisciplinary elements and then apply it to a specific domain through projects and use of specific software
-disseminate the teachings in all the subjects with a general introductory course on ecology and sustainable development.
Both strategies were used in the engineering universities, depending on the skills and interest of the staff of teachers available to teach in the course.

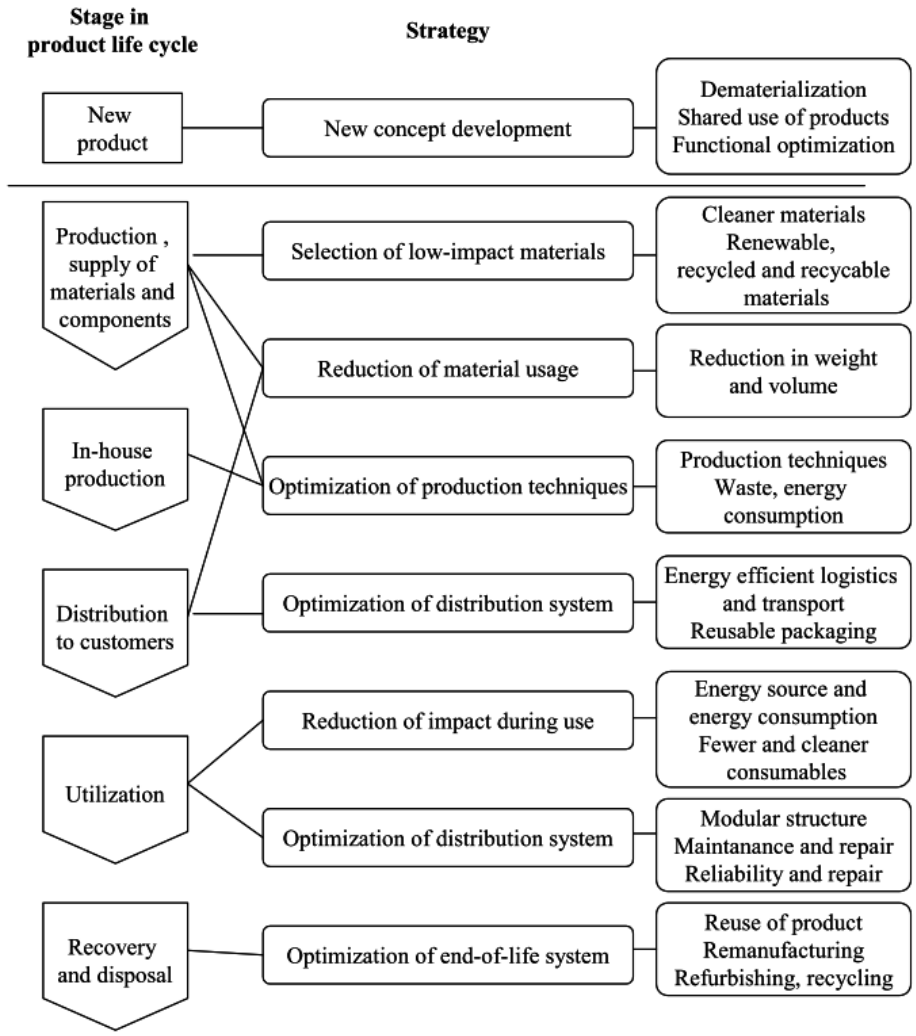

Figure 1: The relation between eco design strategies and product life cycle [3]

2.2 Graduates and carreers

In 2010, In France, there were 80 courses concerning eco design [4].
On *Fig 2*, we can see that in 2009 in France we graduated more than 3000 students each year. Many elements show that eco design has taken a steady place in technological culture for example the fact that in France education before A-level in technological fields now includes eco design (Bac STI2D).
In October 2011, a subject [5] was consecrated to eco design in Techniques de l'Ingénieur, which is the reference handbook for engineers; this means that it became a basic teaching of engineering.

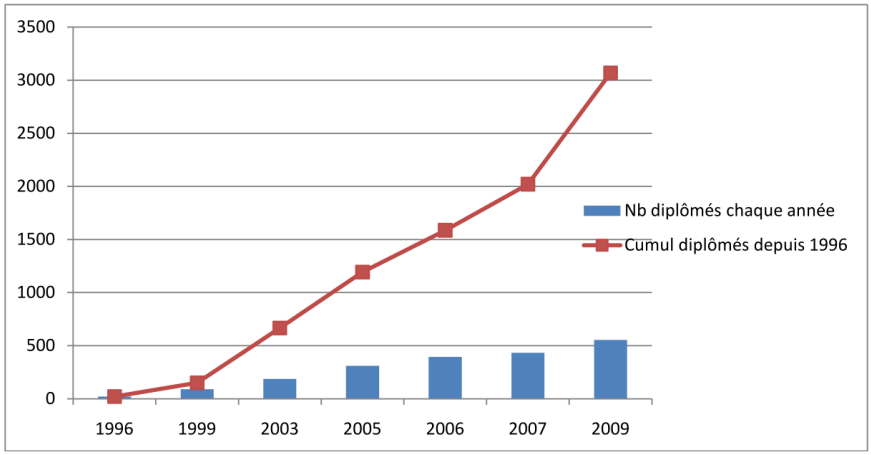

Fig 2: Evolution of the number of graduates in eco design

It is also interesting to observe which jobs are open to those graduates

The definition of the eco design engineers in professional documents for human resources managers is the following:

He assesses the environmental impacts of a product or a process on its whole lifecycle. He takes part to technological choice of components and materials so as to make maintenance and recycling easier. Its main missions are the research of technical solutions and their industrial development:

-preliminary studies and researches to analyze needs, realize LCA, characterize and analyze facts generating ecologic problems, work with production and process engineers to improve sustainability

-make research on new processes or products that could allow reduction of pollution, and energy consumption while taking into account performance, costs and delays

-work on strategic technological watch and innovation

The learning outcomes that graduates must have to allow these employments have also been quoted:

-Scientific and technical knowledge, ability to make measures, analysis, forecasts

-Mastering the global environmental problematic

-Knowledge of eco design tools (LCA) and of the national and European legal referential (REACH, Societal Responsibility of Enterprises, rules on energetic efficiency)

-Knowledge of the regulations about public markets

-Knowledge on materials and processes

-Ability to manage transversal projects and to write technical proposals.

It is clear that only a part of these skills is specific to eco design, the others being skills of classic engineers.

The development of courses of eco-design can be explained by the evolutions of the needs of enterprises; however, there are more needs for senior people in the field than for beginners, because the job needs the knowledge of the relational network of enterprise so as to convince people to change their minds concerning design. This

explains that young graduates very often work in specialized engineering offices that employ experts-consultants or eco designers; these specific offices very often allow enterprises to obtain ISO certifications or eco labels.

2.3 Usual content of courses

We will try to give a synthesis of what is usually taught in classical eco design curricula:

-Generalities on sustainable development and its history; Societal Responsibility of the enterprise, Environmental stakes (water, air, soils, diversity, energy, wastes, pollutions, greenhouse effect)

-Example of eco designed products or processes

-Strategies for Life Cycle Design(reduction of consumption of raw materials, choice of resources and processes, choice of the sources of energy, increase of the duration of life of products, design for dismantlement, recyclability..

-Assessment of impacts, footprint, emissions

-Tools for eco design: LCA, ESQCV, Check lists, software supports, software

-Regulations (VHU, ROHS, REACH, DEEE, EuP, ErP)

-Labels (Ecolabels, Greenpartners...)

- ISO Norms: 14001, 14020, 14040, 14062, 26000)

In some curricula, the link is done with value analysis and functional analysis, but very infrequently with innovation tools such as TRIZ for example.

In computer science curricula, since 2009, impacts of Information technologies began to be quoted.

These contents are those currently met in eco design subjects for engineering curricula. During the same time curricula concerning eco design were developed in schools of design and schools of management. The use was not enough developed to mix studies and projects of engineering and design; so courses were very closed to each other, and for example engineers were neither made sensitive to usage scenarios nor to management of eco design.

3 THE NEW VISION ON ECODESIGN: INNOVATION AND ENTREPRENEURSHIP

3.1 Innovation as an aim for engineers

As we can understand from the previous paragraph, teaching of eco design was for a long time a question of engineers and/or designers.

But during the same time, researches in management sciences showed that there was no contradiction between being a “green enterprise” and a competitive one [6]. At this moment teaching of eco-design was already generalised and sometimes introduced in soft skills teachings; with ISO 14001 Norm, it became part of the teachings concerning SME (Environmental Management System) which is part of the subject “Integrated Management System”. When ISO 14040-LCA norms appeared, it was also a great tendency to include them in the teaching of integrated management subjects.

However in the facts, the two worlds do not mix enough: very often teachers from the management fields feel not concerned by the technology of eco design and the teachers from engineering do not consider the management and economic impact.

The element that make things change is the awareness of the importance of the education of engineers to innovation, and the fact that engineering universities have to develop courses to promote entrepreneurship.
This is the reason why, considering the components on engineering education (*Table 1*) the idea of innovation in a broad sense can be a link between the two approaches (technology and management) of eco design.

Educational Approach	"science-driven"	"market driven"	"socially-driven"
Conception of engineering	(applied) science	economic innovation	Public service
Social role	expert consultant	entrepreneur manager	citizen change agent
Identity, values	academic	commercial	"hybrid"
Forms of learning	"by the book" theoretical	"by doing" practical	"in context" situated

Table 1: Different Approaches to Engineering Education (Jamison [8]

This tendency is reinforced because many people from the world of engineering are interested in research about the meaning of innovation so as to make it more efficient.
Some experts think that it will be necessary to divide our environmental impact by a factor 4 in 2050: the benefits of incremental innovation that can be obtained for example by use of LCA tools will perhaps not be sufficient to arrive to this level.
So, many people think that breakthrough innovation is necessary. Radical innovation proposes not only the research of the direct reduction of impacts but also optimisation of the functionality of the product [9], [10], it is also very concerned by reusability.
That means that methods of innovation and creativity have something to do with teaching of eco design and should be more linked in the head of students and teachers!

3.2 Links of eco design with consumers

Taking in account usages, working with sociologists, ergonomists, designers in a shared global vision is one of the challenges of the future of our engineers.
Slow design for example is a more global view of design it is now considered as a component of eco-design integrating ethics considerations, in link with the education of consumers and to the uses of products and services; it fights against the classical system of production and consumption. For example, planned obsolescence is something which is current for the products we used every day; however this habit should not be considered as compatible with eco designed products!
As eco design has applications in a very large domain and not only for manufactured products, we discover that for sustainable building design for example, the introduction of usages allows to obtain performances that a technical reflection on energetic efficiency alone could not afford.

It is interesting to discover some attempts [*fig3*] to realize eco design through the questioning of stakeholders, this systematic way of thinking could be taught to engineering students.

Fig 3: DTU proposition for eco design reflection [7]

4 CONCLUSION

The development of the teaching of eco-design has not followed the same development in all countries of European Union. During a seminary made in last September for BEST students, I realised that what was considered as basic teaching of our French engineering programs was not even quoted in some other Higher Education Institutions. It is the reason why presenting the evolution of this field is interesting to make each of us meet at an interesting level of approach and share our experiences. Much job is still to be done to integrate these concepts in continuing education and in the criteria of accreditation agencies.

However we can consider eco design teaching as a good example for integration of technology, management and design that should again improve.

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