Education for sustainable development. Case of an Industrial Engineering program in Colombia.

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ABSTRACT

The environmental problems are a reality in the Colombian context and its effects are associated with high costs invested to solve health problems and the damage of ecosystems. Higher education promotes a change of values, behaviors, skills, knowledge that could help humanity to be closer to sustainable development. This is the case of the Eco-design class, part of the environmental management emphasis of the Industrial Engineering program of El Bosque University in Colombia. In this class, pedagogical projects are developed in which students apply and present the gained knowledge during semester in an institutional event every semester. In this paper, is analysed the scope of the projects in accordance with levels of ecodesign application and levels of the evolution of design for sustainability, finding that the class has advanced in the last years generating innovative projects focus on the development of sustainable product-service systems. Moreover, is reviewed how from the class are promoted key sustainable development competences.

Key words: Ecodesign, Design for sustainability, Education for sustainable development, Industrial Engineering Program.

1. INTRODUCTION

In Colombia, the effects caused by incorrect practices from both industry and consumption of goods and services are evident on one hand, in high cost for the country, associated with diseases in the Colombian population. According with a Colombian study the environmental impacts on health due to solid and dangerous waste, water pollution, air pollution, and generation of toxics, involves high costs associated with deaths produced by heart, cerebrovascular and respiratory diseases; which represent almost a third part of the total diseases in Colombia (Ministerio de Medio Ambiente y Desarrollo Sostenible, 2012, p 323).

On the other hand, according with a biodiversity inform in Colombia, "Environmental changes are unleashed mainly due to dynamics linked to mining, agriculture, livestock and urbanization. These dynamics break the natural mechanisms regulation of ecosystems, affecting (in many cases even destroying) its integrity and functionality" (Ministerio de Medio Ambiente y Desarrollo Sostenible & PNUD, 2014, p 40). Moreover approximately the 3,8 % of the Colombian PIB is covering annual costs of environmental damages (Ibid).

According with this Colombian situation is urgent to do education for sustainability because not only the costs invested in water sanitation and hygiene, natural disasters, air pollution and land degradation would decrease but also ecosystems damage and human diseases. In that sense, Education for Sustainable Development (ESD) is an urgent need for Colombians in order to allow them "to acquire the knowledge, skills, values and attitudes that empower them to contribute to sustainable development and take informed decisions and responsible actions for environmental integrity, economic viability, and a just society for present and future generations. […]" (UNESCO, 2018, p 41). Consequently, from the program of Industrial Engineering, Education for sustainability is promoted with its emphasis on Environmental management.

1.1 Background of the study

Eighteen years ago the program of Industrial Engineering of El Bosque University has been developing an emphasis on environmental management for this career. The program achieve this emphasis through 3 classes: The first one ecology, the second one Eco-design and the third one Environmental management. This paper will focus on how is promoted education for sustainable development from the Eco-design class in students, analysing their final projects of the semester from 2011 to 2018 and also the evolution of the program during this period of time.

The Eco-design class is addressing the development of products and services with an ecological approach taking into account the methodology of eco-design and its strategies, as well as the life cycle assessment of the products, to reduce environmental impacts during their life cycle and contribute to the sustainable production and consumption from the industry.

The general contents of the class during the period 2018 – 1 were:

- Product life cycle. Life cycle analysis tools (qualitative and quantitative). Environmental problems.
- Eco design and sustainability. Methodology. Strategies. Closed cycle (technical and biological). Sustainable Product Service System. Circular economy.
- Eco product design for environmental and business improvement (project). Ecolabelling Eco-innovation.

The theoretical background during the Eco-design class is:

- Eco-design (Life Cycle design), "is considered a practical mechanism for integrating environmental considerations throughout the life cycle of the product" (Luiz, Jugend, Jabbour, et al., 2016).
- Life Cycle Assessment: Methodology that evaluates the environmental impacts associated to processes and materials of the life cycle of a product or service in relation to its functional unit (Vezzoli & Manzini, 2015).

- "Circular Economy (CE) aims to overcome the take-make-dispose linear pattern of production and consumption, proposing a circular system in which the value of products, materials and resources is maintained in the economy as long as possible" (Merli, Preziosi, & Acampora, 2017). The model of circular economy also called "economy from cradle to cradle" or "closed-loop economy" (Ellen Macarthur, 2013).
- Product service system design for sustainability is:

"the design of the system of products and services that are together able to fulfil a particular customer demand (deliver a 'unit of satisfaction') based on the design of innovative interactions of the stakeholders (directly and indirectly linked to that 'satisfactio n' system) where the economic and competitive interest of the providers continuously seeks both environmentally and socio-ethically beneficial new solutions" (Vezzoli, C., Kohtala, C., Srinivasan, et al., 2014, p 50).

From Eco-design class is promoted Education for sustainable development through applied projects during the semester very close to reality and the best projects are presented in a semiannual event organized by the Industrial Engineering program, called Responsible Production and Consumption. Through the development of the projects, students are encouraged to innovate and get new solutions to products and services found in the market. From this perspective, the students are stimulated to change their values and attitudes towards what means sustainability and how they can contribute to sustainable development from their professions working for industries and as daily consumers too.

2. METHODS OF ANALYSIS OF THE STUDY CASE

As part of the pedagogical focus on Eco-design class, students ought to present a project where they should apply the theoretical knowledge acquired during class. In the present document are analysed the projects presented by students from semester 2011 to 2018 (7 years).

The students projects will be analysed taking into account four levels of the evolution of design for sustainability and the four levels of eco-design application as the following table shows:

[Table 1] Evolution of design for sustainability and Ecodesign application levels *(Font: Ceschin & Gaziulusoy, 2016, Balboa & Domínguez, 2014)*

Evolution of design for sustainability Levels	**Ecodesign application Levels**
Level 1. Product design innovation: "design approaches focussing on improving existing or developing completely new products".	**Level 1. Product improvement:** progressive and incremental improvement.
Level 2. Product-Service System innovation: "here the focus is beyond individual products towards integrated combinations of products and services (e.g. development of new business models)".	**Level 2. Redesign of the product:** new product based on another existing one.
Level 3. Spatio-Social Innovation: "here the context of innovation is on human settlements and the spatio-social conditions of their communities. This can be addressed on different scales, from neighbourhoods to cities".	**Level 3. New product in concept and definition:** radical innovation of the product.
Level 4. Socio-Technical System Innovation: "here design approaches are focussing on promoting radical changes on how societal needs, such as nutrition and transport/mobility, are fulfilled, and thus on supporting transitions to new socio-technical systems".	**Level 4. Definition of a new system:** radical innovation of the system.

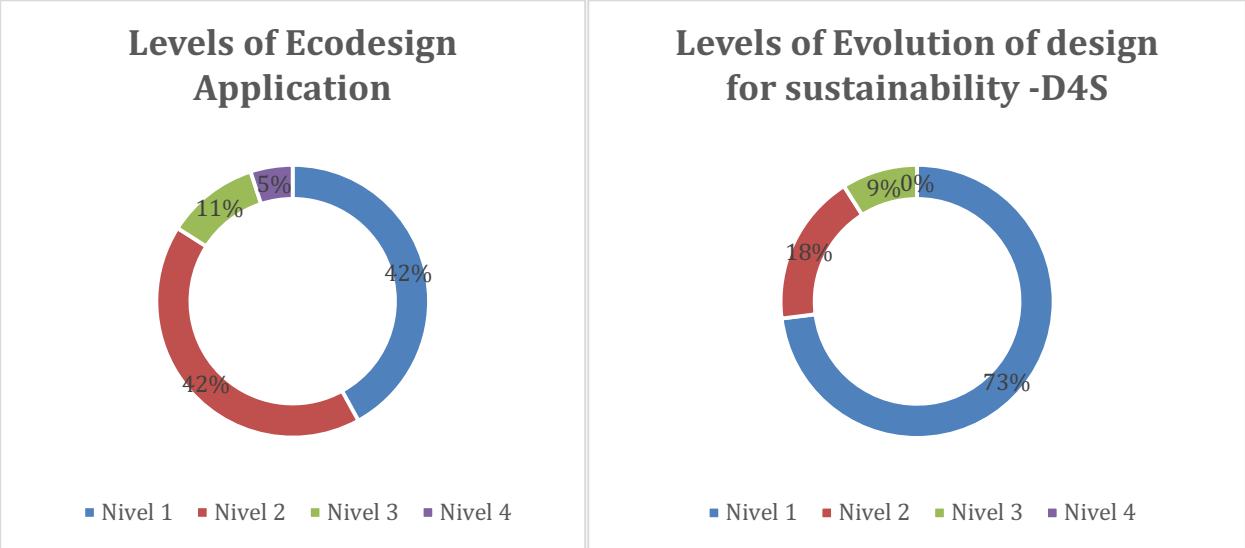
Moreover there is an analysis about how from the Ecodesign class are promoted the 8 key sustainable competences defined by UNESCO (2018).

3. RESULTS AND DISCUSSION

3.1 Analysis about the projects developed by students of Ecodesign class

The analysis of information of the students Eco-design projects during the last 7 years make evident that the proposals designed by students in their projects at the end of the semester from 2011 to 2016 are mainly focused on product improvement (level 1 – 42 %), and redesign of the product (level 2 – 42 %), according with levels of eco-design application. In relation with the evolution of design for sustainability levels the projects has been focus mainly on product design innovation with a 73% (level 1).

From 2017 has been evolving the innovation of the projects and its scope creating solutions, which apply Ecodesign in levels 3 and 4. New product in concept and definition with an 11% of projects (Level 3) and Definition of a new system with a 5% of projects (Level 4). In the case of the levels of evolution of D4S the projects have evolved providing solutions focus on level 2 and 3. Product-Service System innovation with an 18 % of projects (Level 2) and Spatio-Social Innovation with a 9 % of projects (Level 3). (See figure 1).



[Figure 1] Analysis of levels of Ecodesign Application and evolution of D4S in students´ projects *(Font: Archives of Ecodesign class 2011 to 2018)*

The reasons for the evolution of the application of eco-design and the evolution of D4S the last years could be the following: In 2016, the University organized the 2nd Ecodesign Latinamerican Congress, one of the results of this event was to make part of the Learning Network on Sustainability (LeNS) with the launching of the Colombian LeNS Network. The participation of both the professor and students in this network has open new knowledge windows, which have widen the scope of the class, teaching to the students new systemic paradigms that are not only related with the improvement of a product from the environmental perspective. On the contrary in these new perspectives, solutions are more complex and must be designed new business models where are different stakeholders involved in order to achieve the satisfaction of economic, social and environmental needs expressed in Sustainable development goals.

Below are some examples of how the results of the projects proposed by students from the Ecodesign class have evolved:

Proposal of a bubble gum packaging (2012)
A bubble gum packaging is redesigned with the aim of reducing the environmental impact caused by the use of the materials in the current chewing gum packaging. The mono-materiality ecodesign strategy is applied, going from 3 materials in the current product to 1 in the proposal proposed by the students (Galan et al., 2012).

Proposal of a tooth paste packaging (2014)

Redesign of monomaterial packaging reducing the use of 3 of the materials of the product: aluminum, polyethylene and cardboard. In addition, the primary packaging is redesigned so that it can be refilled when the toothpaste is finished (Montoya et al., 2014).

Proposal Alumilk (2018)
Students propose Alumilk a company dedicated to the production of aluminum can packaging as an alternative to Tetra Pak packaging focused on the sale of milk. Despite the impact caused by aluminum in its extraction, a system is proposed that uses aluminum so that milk can be recharged in this type of packaging and consumers pay for milk recharge. At the end of the useful life of the packaging, the company is in charge of recycling the packaging so that it can be part of the technical cycle again (Bedoya, Medina & Olmos, 2018).

Proposal to reduce the consumption of water in a rural area in Colombia (2018)
Within the framework of the 3rd meeting of the LeNS Colombia Network, an inter-institutional workshop was held on the 25-liter water challenge promoted at the international level by the Open Source and Circular Economy days network. From the ecodesign class of the Industrial Engineering program were proposed alternatives to close the water cycle using living organisms to purify water, and other purification technologies to reuse water in showers, sinks, and dishwashers. Moreover, a dry bath proposal was developed in order to avoid the use of water in the bathroom and take advantage of human waste in other processes.

As the examples above show, students have evolved in their learning on sustainability, going over the improvement of a product from its environmental life cycle perspective, towards new models of business or the solution of complex systems. This new perspective implies to take into account the interconnectedness of the improvement of products, services and systems in order to bring more sustainable solutions. It means, the solutions should have economic, social and environmental benefits. For example, the project focus on the access to freshwater for a rural community during all the year. The solution generated by students promote the rational use of water through its purification and reuse. It is beneficial for the environment because the community will not generate polluted water, and at the same time, they optimize their use having access to potable water during the entire year, which will be socially and economically beneficial.

3.2 Key sustainability competencies promoted from Ecodesign class

According with UNESCO (2018), there are eight key sustainability competencies to have in mind for education, in the following table are analysed how through the Ecodesign class are developed some of this competences in order to promote in the students to think and act in aid of sustainable development.

[Table 2] Key sustainable competences promoted in Ecodesign class *(Font: Adapted from UNESCO, 2018 pag. 44)*

Key Sustainability competences	How are promoted in Ecodesign class
Systems thinking competency: the ability to recognize and understand relationships, to analyse complex systems, to perceive the ways in which systems are embedded within different domains and different scales, and to deal with uncertainty;	Students analyse the life cycle of a product and they create solutions focus on Sustainable Product-service systems or solutions from the perspective of Cradle to cradle, which promote new model business.
Anticipatory competency: the ability to understand and evaluate multiple futures – possible, probable and desirable – and to create one's own visions for the future, to apply the precautionary principle, to assess the consequences of actions, and to deal with risks and changes;	Students compare the solution proposed with the initial diagnosis of the project that they develop during class through quantitative and qualitative tools.

Normative competency: the ability to understand and reflect on the norms and values that underlie one's actions and to negotiate sustainability values, principles, goals and targets, in a context of conflicts of interests and trade-offs, uncertain knowledge and contradictions;	Students reflect about how their solutions are responding with the Sustainable development Goals.
Strategic competency: the ability to collectively develop and implement innovative actions that further sustainability at the local level and further afield;	The development of the projects during semester, look for the achievement of sustainable production and consumption patterns; however, any of the projects has been implemented in reality.
Collaboration competency: the ability to learn from others; understand and respect the needs, perspectives and actions of others (empathy); understand, relate to and be sensitive to others (empathic leadership), deal with conflicts in a group; and facilitate collaborative and participatory problem-solving;	Students should develop a project working in groups' maximum of 4 students, and they should solve the situation.
Critical thinking competency: the ability to question norms, practices and opinions; reflect on own one's values, perceptions and actions; and take a position in the sustainability discourse;	They argument why from the sustainable perspective it is better the solution they design.
Self-awareness competency: the ability to reflect on one's own role in the local community and (global) society, continually evaluate and further motivate one's actions, and deal with one's feelings and desires;	Students individually perform a reflective essay about their role as consumers to reduce environmental impacts and the importance of ecodesign in the industry to promote consumption and sustainable production in the business context from Industrial Engineering.
Integrated problem-solving competency: the overarching ability to apply different problem-solving frameworks to complex sustainability problems and develop viable, inclusive and equitable solution that promote sustainable development – integrating the above-mentioned competencies.	As Industrial Engineerings students are trained to solve problems, in Ecodesign class they must solve different situations detected through tools learned during the semester and apply solutions from different design for sustainable approaches.

In conclusion, the Ecodesign class belonging to the program of Industrial Engineering as an emphasis of environmental management help students to develop the key competences to achieve sustainable development: Systems thinking, anticipatory, normative, strategic, collaboration, critical thinking, self-awareness, and integrated problem –solving competences. However, the weaker competences could be anticipatory and normative since the class has not the normative emphasis and it is not focus on future scenarios. The other 6 competences are strongly developed through the semester project which they develop in groups in a collaborative way.

"Sustainability performance depends on the interplay of knowledge and skills, values and motivational drivers, and opportunities. The interrelation of these dimensions influences personal behaviour" (UNESCO, 2018), according with this statement, the Ecodesign class is an opportunity for students to acquire knowledge and skills about sustainable consumption and production and apply this knowledge through semestral projects, nevertheless to change values and generate motivational drivers is a challenge

for the Ecodesign class in four months of study. In that sense, should be mandatory to apply what the students learn in this class in projects the students develop for other classes and in other semesters.

4. CONCLUSSIONS

As well as the design of sustainable product – service systems need the association of several actors to satisfy a need. In the same way, in education for sustainability, it is necessary to have the association of several actors, either from other university institutions at a national or international level or other actors in society, government or companies, so that the ideas generated by the academy can be nurtured and implemented in reality. An example of that is how Ecodesign class has evolved thanks to the interaction with local and international professors belonging to the Learning Network on Sustainability. Consequently, the development for sustainability won´t be a distant goal, but an activity that we do every day from different professions. The case of the Ecodesign class immersed in the career of Industrial Engineering is an example of how these strategies should be applied transversely in the curricula of all professions, as is the case of transversal environmental projects in pre-school, basic and media education in Colombia.

Educate for sustainability is a key point to achieve sustainable development goals, from the class are promoted key sustainable development competences such us: systems thinking, strategic, collaboration, critical thinking, self-awareness, and integrated problem –solving competences. These competences could be reinforced with the application of knowledge and skills of the class in other classes and other projects of other semesters in the career. It will be useful to strengthen values and motivational drivers in students and professors to behave in a sustainable way as consumers and to influence producers for sustainable practices.

The Eco-design class has had impact on more than 1000 students from 2011. This impact is evident in student's participation on academic activities such as: presenting their Eco-design class projects in national and international events through presentations, posters, and papers, the development of degree works on topics related with the class that benefit real Colombian companies. All this interaction with academic and business context helps to appropriate what it means sustainable development and to put in practice this knowledge learned to the service of others.

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