INTEGRATING SUSTAINABILITY AS A CRITICAL SKILL IN A CDIO "PRODUCT DEVELOPMENT" COURSE

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ABSTRACT

There is a pressing need to formulate and implement engineering solutions that guarantee both environmental and social sustainability in a world facing severe challenges identified in the global agenda through the Sustainable Development Goals (SDG). Consequently, sustainability is increasingly recognized as an essential outcome in engineering curricula all over the world. Despite recent efforts to include sustainability in the scope of engineering CDIO projects, there is a lack of a common framework to consider sustainability and specific methodologies to achieve the essential integration of strategic, social and environmental issues in this type of courses.

The INGENIA courses, based on the CDIO paradigm, taught in the first year of the master in industrial engineering at the Technical University of Madrid (UPM) are trying to consider systematically the different dimensions of sustainability to provide future engineers with the necessary skills to successfully incorporate sustainability in their work. This contribution presents a case study to illustrate and assess the methodology used to integrate sustainability as a critical skill in a product development CDIO course specifically. This methodology intends to incorporate environmental, social, ethical and other strategic factors related to the global sustainability of a product even before the design stage. Improvement potential from the sustainability point of view is considered as a key factor to define the prototype basic design and capabilities. Stakeholders and environmental opportunities are analysed along the market study and business plan. Later on, during the design stage environmental and social issues are included as design rules to identify optimal engineering solutions under a life cycle assessment (LCA) perspective.

The INGENIA "Product Development" course has been running for three years now. In this paper, we describe how the CDIO experiences have evolved and the corresponding assessment of sustainability skills of our students according to our experience. Further challenges and potential improvements are also discussed.

KEYWORDS

Sustainability, CDIO product development course, Case studies & best practices, Engineering Design, Mechanical Systems, Machines Engineering. Standards: 1, 3, 5, 7, 8.

INTRODUCTION

It is widely recognized that the world faces serious challenges concerning sustainability. The international agenda to end poverty and protect the planet are is defined through the Sustainable Development Goals (SDG) (United Nations, 2016). Tackling this issues implies the involvement of governments, companies and civil society. Engineering also plays an important role in the achievement of these targets. In particular, engineering may help decoupling human well-being from resource depletion as well as social and environmental impacts. This is the reason why it is essential to drive engineering education beyond technical skills (Hernandez Bayo et al., 2014) and integrate sustainability in the development of processes, products and systems in general.

The Escuela Técnica Superior de Ingenieros Industriales of the Universidad Politécnica de Madrid (School of Industrial Engineering, Technical University of Madrid (ETSII-UPM hereafter), launched in 2014-15 the new Master's Degree in Industrial Engineering which includes a series of INGENIA subjects (Lumbreras et al., 2015; Lumbreras et al., 2016) based on the teaching-learning CDIO standards, covering the majors included in the curriculum (Table 1).

Table 1. Available "INGENIA" courses in the 2016-2017 academic year

Different INGENIA Subjects	**Product / system developed & objective**
Automotive Engineering: Formula SAE	Students take part in the complete development project of a competition car, from the conceptual design, to the final competition.
Product development	Students live the whole process of creating an innovative machine, from the conceptual design stage, to the final trials with real prototypes, searching for design improvements.
Everyday life products / household goods	Students live the whole process of designing innovative products, from the concept step, to final simulations and trials with prototypes.
Systems engineering	Students experience the process of designing a smart system, using state-of-the-art engineering resources and taking account of the whole life-cycle. (A set of co-operative drones in current year).
Electronic devices: The School of the future - Smart ETSII	Students live the whole process of creating a new electronic product, oriented to improving everyday life in our ETSII-UPM, from the concept, to the prototyping stage and trials.
Industrial construction projects	Students experiment with information management and project planning resources applied to a real industrial construction project (a beer-factory in current academic year).
Electrical systems design	Students live the development project of an electricity supply network, from an initial renewable energy source to population.
Biomedical engineering design	Students experience the process of creating an innovative medical device, from the conceptual stage, to the final trials with prototypes.
Videogames design	Students conceive, design, implement and debug a software system, mainly videogames or emulators that are built taking into account the mathematical and physical basis of the problem being addressed.

Acoustic Engineering industrial applications	Students face the design and implementation of engineering solutions from the acoustic perspective in the scope of industrial, transport and environmental sectors.
Computer-aided Engineering	Students participate in the design of advanced, new materials with practical applications to social needs (shape-memory polymers and biomimetic and self-assembling materials) in a collaborative environment.
Motor-Gen: design and manufacturing of a thermal engine	Students design and build a thermal engine by reusing existing materials and artefacts working in multi-disciplinary teams.

These subjects are 12 European Credit Transfer System (ECTS) equivalent, structured in three modules:

- Module A (Technical): 30 hours dedicated to adapt basic theoretical knowledge derived from other subjects to those directly related with the project, and a second set of 60 hours is devoted to practical work in the lab, with professor supervised sessions.
- Module B (Transversal skills): 15 hours for workshops to improve skills and techniques on teamwork, communication, and creativity.
- Module C (Sustainability): 15h for lectures and workshops about environmental and social impacts, ethics, and, professional responsibility.

Module C of INGENIA courses are intended to include a series of items of the CDIO Syllabus 2.0 directly related to sustainability (Miñano et al., 2016). However, there are few references regarding effective teaching and learning strategies that holistically and systemically address the integration of sustainability in CDIO courses (Brodeur, 2013). Despite the development of a general conceptual framework for the integration of these outcomes within INGENIA courses, briefly described in the following section, there is a clear need for further work to guarantee that fundamental sustainability principles are intimately integrated in each of the INGENIA courses, taking into account their particularities and specific teaching methodologies. This contribution reports on the activities done and main prospects to achieve this target within the "Product Development" course.

GENERAL FRAMEWORK FOR THE INTEGRATION OF SUSTAINABILITY INTO CDIO COURSES AT ETSII-UPM

The methodology developed to systematically consider the different dimensions of sustainability, including ethical and strategic aspects in CDIO courses at ETSII-UPM is presented in Miñano et al. (2016). It is based on a practical approach that enables to consider sustainability and ethical issues by a systematic exploration of all lifecycle phases. Besides providing a holistic view needed to avoid negative impacts (Cheah, 2014), it allows the identification of new functionalities and options to improve the product being developed. This methodology tries to assess the three classic dimensions of sustainability (economic, environmental and social), emphasizing that all of them have to be deeply grounded on the ethical and professional responsibility. Honesty and ethical compromise is identified by the employers or our graduates as the most valuable outcome (Fundación everis, 2016). From the academic perspective, reflecting on the ethical and professional responsibility dimensions of their work helps the students understanding the importance of social and environmental impacts of the products they develop. A fourth strategic dimension intends to integrate all economic, environmental and social considerations under a unified long-term, shared-value creation perspective. These aspects cannot be studied separately, that's why the methodology proposed also includes the relationships with the different stakeholders that may be affected by the technology/service/artefact developed in the project (Figure 1).

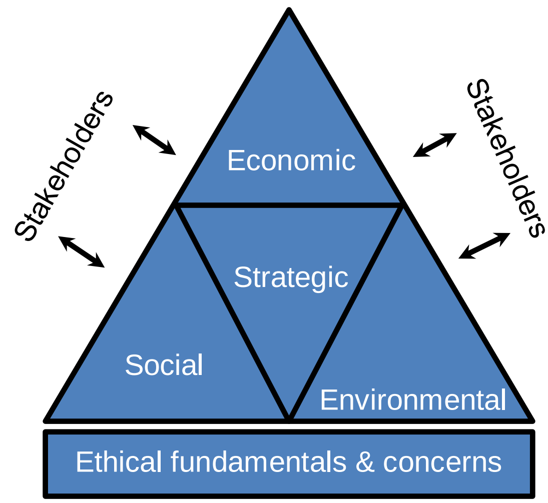

Figure 1. Framework for integrating sustainability and ethics in the INGENIA subjects (Miñano et al., 2016)

Early in the CDIO course, the students are asked to perform a first screening of the possible ethical, social and environmental issues related to their project in the context of a previous analysis of the technological sector the project is framed in and its organizational specificities. In the second phase, students have to select the most relevant issues to their project from the ones identified in the previous step, and analyze them in depth while working in design and implementation of their project. Different methodologies are proposed for environmental and social analysis. The environmental analysis is loosely based on the Life Cycle Assessment (LCA) methodology, generally recognized as a useful approach to integrate sustainability into CDIO-based engineering courses (Jeswiet et al., 2005). In the case of social impact, a selection of the most relevant impacts is discussed and agreed so the students can think of the consequences of each of them and analyze their capacity to influence them. To make the process more effective, the working teams are asked to identify relevant stakeholders, regulations, laws, ethical codes related, etc. and pondering on the possibilities of an assessment or quantitative evaluation of the impact.

The third phase within module C aims at quantifying and measuring the impacts selected in the previous phase. When possible, the students will test the product, studying the interactions with potential users or affected groups, so as to contrast the expected impacts or to identify new ones. Although this is highly variably depending on the project nature and it is not always possible the students are asked to produce a final report where they have to reflect on this impacts and justify how the design of their product/service incorporates the constrains and opportunities related sustainability issues.

While this general approach has been found useful to integrate sustainability issues in CDIO courses, the wide range of activities covered by INGENIA courses (Table 1) and the particularities related to specific teaching-learning approaches and specific course planning make it necessary to perform a more detailed analysis on how module C can be integrated more effectively in every specific course, such as the one on product development discussed in this contribution.

PRODUCT DEVELOPMENT COURSE

The Product Development course (Proyecto de máquinas) (Munoz-Guijosa et al., 2016) is one of the INGENIA courses offered by the Department of Mechanical Engineering at ETSII – UPM, a Department with extensive experience with CDIO courses (Díaz Lantada et al., 2013; Chacón Tanarro et al., 2015). Students must Conceive, Design, Implement and Operate a product selected by themselves, taking into account sustainability issues during the whole course. Students work in 8-10 people groups, working on separated projects/products (3 or 4) and playing different roles during the course. The main tasks carried out during the course are:

- Product proposals
- Patent study
- Market study
- Product planning
- Business plan and risk analysis
- Pricing
- Concept design
- Basic and detailed engineering
- Computer Aided Engineering (CAE) and simulation: finite element methods (FEM)
- International sourcing
- Prototype manufacturing/testing
- Environmental and social analysis
- Redesign and documentation
- Reporting and presentations

The course also pursues the objective of making the students discover how technical knowledge and competences in acquisition during their studies can be applied in a project with real life constraints. They are free to choose the product in which they will be working the whole year. The only requirement is that it has to be an innovative electromechanical product which can be patented. 7 professors are available within module A to help and guide *students* during the project. Short lessons are taught every two/three weeks about the basics of every project stage and the tools to apply this theory to their product. They also have to deal with suppliers, fund providers, deadlines, complex equipment and processes and many other challenges that are usually present in real engineering projects.
Figure 2 shows the course schedule, which already includes sustainability classes, which will be discussed later on in this article. This INGENIA is intended as a complete course that tries to empower the students and give them the opportunity to fully develop their own ideas using all the resources available in the university.

As an example, Figure 3 shows the product “Flabellum”, an automatic sunshade that automatically moves during the day in order to counteract the sun’s movement so the shade keeps in the same position. Students worked very hard and finally achieved the objective: to have a 100% working prototype at the deadline stablished. They learned how to design thinking on the whole product lifecycle, including its impact on society and environment. They also learned to use rapid prototyping equipment, designed and programmed the electronics, and also learnt welding, cutting, sanding and many other workshop jobs that were needed to manufacture it.

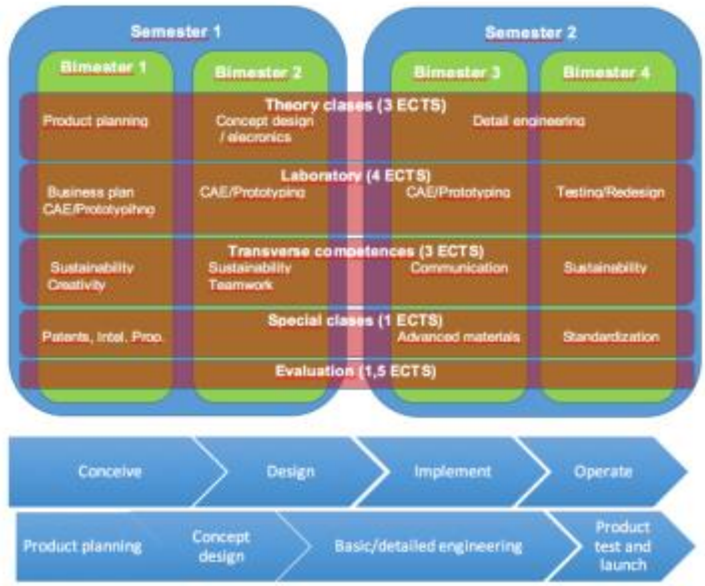

Figure 2. Product Development course schedule

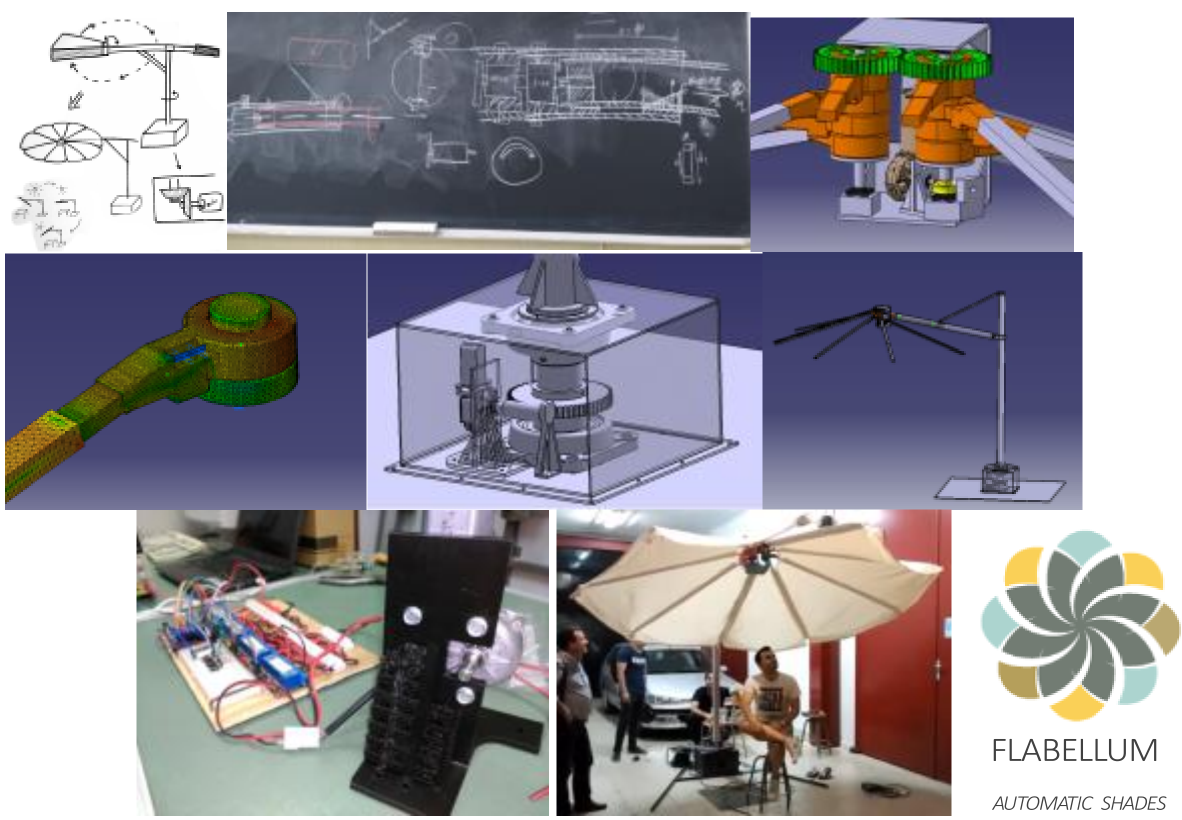

Figure 3. Different stages of the product development: concept design, CAE assembly check, FEM structural and thermal analysis, electronics software and hardware development, product testing.

In particular, sustainability issues are considered during the whole development process in the following aspects:

- During the product planning phase, not only economic considerations, regarding the objective cost and development deadline to guarantee the profitability of the project but also sustainability issues are taken into account. The selection of the functionalities the product must incorporate social and environmental considerations, in order to fulfill, for instance, work safety and ergonomics regulations, emission standards or ethical conflicts –worker reduction due to automatization, sourcing at underdeveloped countries, etc-. Social groups impacted by the product introduction must also be determined, and a particular study about one of them must be carried out (see implementation section).
- During the concept design phase, considerations regarding product performance and consequently energy efficiency are an important evaluation criteria in order to make decisions about the working principles which will be further developed. In the manufacturing process design, criteria as minimizing warehouse stock or internal movements, as well as waste products handling and minimization, are also discussed.
- During the basic and detailed engineering stage, students take into account, for instance, the existing regulations regarding forbidden materials. They must also select, among the feasible materials, the ones with smallest energy content and minimum environmental impact along their life cycle. They must also introduce design decisions regarding recyclability, as not mixing materials which will suffer different recycling processes, or selecting solutions for connecting parts which allow for an easy disassembly in the case the connected parts must be separated for recycling. A report regarding the lifecycle environmental profile must be carried out (further details are given in the following section).

IMPLEMENTATION

The integration of sustainability into the “Product Development” INGENIA has evolved during the three editions of the course. The implementation described in this section correspond to the current approach based on the principles highlighted in previous sections and the experience from previous courses.

Course modules and planning

Activities within all INGENIA courses are arranged according to the 3-module structure briefly discussed in the introductory section. Although sustainability factors are considered throughout the entire project, 11 hours of specific sessions to discuss these issues (Module C) are included in the teaching planning of the Product Development Course. The 4 hours not allocated in the teaching plan (Figure 4) are used for tutoring classes outside the days specifically devoted to INGENIA (Mondays).

INGENIA PROYECTO DE MÁQUINAS 2016-2017

	FIRST BIMESTER (FIRST SEMESTER)					
	5-sept	12-sept	19-sept	26-sept	10-oct	17-oct
	Events hall	Room 33	Room 33	Room 33	Room 40	Room 40
8.30-9.20	Subjects information	PRESENTATION OF OTHER YEARS	Tools for problem solving	PRODUCT VOTING	TEAMWORK WORKSHOP S1	PRODUCT PLANNING PRESENTATION 1
9.30-10.20						
10.30-11.20		The need of product development systematics	Problem solving in-class event	Product planning theory	SUSTAINABILITY S2	
11.30-12.20		Tools for problem solving				Product planning improvement
12.30-13.20		SUSTAINABILITY S1	Product planning theory			

	SECOND BIMESTER (FIRST SEMESTER)					
	7-nov	14-nov	21-nov	28-nov	5-dic	12-dic
	Room 40	Room 40	Room 40	Room 40	Room 40	Room F10
8.30-9.20	Concept design theory	CONCEPT DESIGN PRESENTATION 1. SUSTAINABILITY REPORT 1 DEADLINE	CONCEPT DESIGN PRESENTATION 2	SUSTAINABILITY S3	ELECTRONICS SEMINAR	Basic engineering in-class work
9.30-10.20						
10.30-11.20			Basic engineering theory			
11.30-12.20	Concept design in-class work	Concept design improvement work		Basic engineering in-class work		
12.30-13.20						
	PRODUCT PLANNING PRESENTATION 2					

	FIRST BIMESTER (SECOND SEMESTER)					
	6-feb	13-feb	20-feb	6-mar	13-mar	20-mar
	Room 33	Room 33	Room 33	Room 40	Room 33	Room 40
8.30-9.20	Basic engineering theory	BASIC ENGINEERING PRESENTATION 1	Basic engineering improvement in-class work	BASIC ENGINEERING FINAL PRESENTATION, WITH CARDBOARD PROTOTYPES	Detail engineering in-class work	Detail engineering in-class work
9.30-10.20						
10.30-11.20						
11.30-12.20		Basic engineering improvement in-class work		Detail engineering theory	SUSTAINABILITY S4	Detail engineering theory
12.30-13.20						

	SECOND BIMESTER (SECOND SEMESTER)					
	27-mar	3-abr	24-abr	8-may	19-may	29-may
	Room 33	Room 40	Room 33	Room 33	Room 40	Room 33
8.30-9.20	Detail engineering in-class work	Detail engineering in-class work	DETAIL ENGINEERING PRESENTATION 1	Standarization seminar	TESTING AND REDESIGN	FINAL PRESENTATION
9.30-10.20	COMMUNICATION WORKSHOP					
10.30-11.20				TESTING AND REDESIGN		
11.30-12.20	TEAMWORK WORKSHOP S2	Patenting and IP theory	SUSTAINABILITY S5			
12.30-13.20					Preparation of public presentation	

Figure 4. Complete subject class teaching planning including sustainability (module C) classes

Teaching-learning methodology

Classes devoted to module C include lectures and workshops about environmental and social impacts, ethics and professional responsibility, as follows:

- The first class at the beginning of the course (S1 in Figure 4) consists of an opening lecture common to all the INGENIA courses' students, before they even know the actual project they will be working throughout the year. The main challenges the Planet faces are presented and the fundamentals of sustainability briefly discussed. Then the basic 3-stage methodology (Miñano et al., 2016), expected outcomes and conceptual framework of module C (Figure 1) are introduced. The main concepts and tools relevant for environmental, social and ethical assessment are presented along with the reference materials and tools. For a better understanding of social and environmental implications of Engineering practice as well as ethical and professional responsibility, students are asked to check the reference materials (reports, videos and other online resources) before the first sustainability session within their specific INGENIA. This session is deemed essential to raise students' awareness towards their responsibility and potential contributions to sustainability through their professional activity.
- Unlike other INGENIA courses, the products to be developed in the "Product Development" course are not defined beforehand. Despite providing the theoretical basis for product planning and problem solving, the first sessions within module A are used to discuss potential products to be developed during the course. The second sustainability session (S2 in Figure 4) is scheduled right after the products to be developed (3-4 every year) have been agreed through a voting procedure (Munoz-Guijosa et al., 2016). During this session (3 hours) the reference materials are discussed and a more specific lecture regarding sustainability is given in the mechanical engineering sector, highlighting important stages and potential relevant issues (e.g. energy and material fluxes throughout the product life cycle). It is particularly relevant to include a brief workshop regarding stakeholders during this first specific interaction with the students. This has been found determinant for the

successful incorporation of social and environmental considerations and the selection of the functionalities the product must incorporate during the product planning phase. At the end of the session, the working groups are given their first assignment that consist of a first sustainability report (the basis for the final deliverable) that includes the analysis of stakeholders throughout the product lifecycle as well as the basic environmental life cycle assessment flowchart. Although at this stage the details regarding the different stages (resource extraction and processing, design, manufacturing, distribution, use, collection and recycling/disposal) are not known, this exercise is very interesting for them to gain a better understanding of the potential implication of their product from a wide perspective and thus, to include this kind of considerations into their designs.

- The next session (S3, 3 hours) is scheduled 1.5 months later, after the concept design is completed. Product working principles and manufacturing process are already defined and incorporate sustainability criteria identified in the first stage of module C. In this class all interim reports are given feedback and there is an open discussion on the deliverables since many points raised in the revision of the documents are relevant questions to more than one group, regardless of their product particularities. As students progress in their designs, sustainability criteria are reviewed and relevant social and environmental issues are clearly identified. The assignment for the following class includes the amendments of the sustainability report and the proposal of topics for detailed assessment within module C. There are no hard rules to address the third stage of assessment and each group decides the more convenient approach and justification to define the boundaries of a subsystem for detailed analysis and impact quantification, when possible.
- The groups are given 2.5 months to work on their sustainability report so they present a first complete draft version in S4 (2 hours) after completion of the basic engineering stage. Students are encouraged to arrange office hours between sessions S3 and S4. Nevertheless, feedback on the previous deliverable is given as well as orientation for the final report.
- After the detailed engineering stage is accomplished, a general assessment of the sustainability dimension of the project is done and options to polish the final draft of each group are discussed during session S5 (2 hours).

Teachers' activities

At least two professors are appointed to supervise the learning process and integration of module C in the Project Development Course. These two faculty members have different expertise areas and have a focus on either environmental or social/ethical dimension of the project. During the whole course, faculty members participate in the sustainability sessions previously described and are responsible for giving feedback on the deliverables sent by the students as well as offering office hours to clarify concepts and discuss strategical issues. According to our experience, a close cooperation and coordination with professors from module A is essential to convey a coherent message and to achieve satisfactory results.

Students' activities
All the assignments within module C are proposed as group activities (students are grouped in relatively big teams of 6-12 people each) although usually a group member is appointed as the responsible to make the necessary coordination and linkage with module C teachers. Group members may take responsibilities on specific tasks or research needs to put together the sustainability report but special emphasis is made to guarantee that all of them are perfectly aware of principles, as well as design and implementation decisions with implications on sustainability. The amount of work envisaged for module C is equivalent to 1.5 European Credit Transfer System (ECTS), so the workload expected for each students regarding specific sustainability activities ranges between 37.5 to 45 hours.

Tools
A specific section including materials and assessments of module C is available at the moodle of the INGENIA course. The main reference materials are:

- Teaching guide: responsible faculty members and logistics, aims, methodology (3-stage assessment), planning, resources, evaluation criteria and annexes: procedures and indicators for each of the methodological stages, structure and format of the sustainability report and checklists for the identification of social an environmental relevant issues.
- Sustainability fundamentals: document to provide the scope of sustainability with links to online resources and videos
- Slides of the opening lecture: introduction to sustainability, global challenges, rationale and scope of module C, details of the methodology and examples for qualitative and quantitative analysis and further references.

Deliverables
Key guidelines for dealing with this holistic integration were developed and made available to students. Inspired by the Value-Sensitive Design method and other experiences mentioned in the literature review, we established four phases to carry out the works: identification of possible impacts, analysis and selection of the relevant issues, the technical phase, and a final reflection covering all the dimensions of sustainability. This is reflected in the structure of the sustainability report that each group has to produce during the course. The work done in this area has to be synthesized in a very concise document where an account of the main relevant issues and stakeholders are given as well as qualitative and quantitative analysis regarding the social and environmental dimension of their products. The students are asked to conclude by providing a justified assessment on how sustainability criteria have been integrated into their prototypes and how they add value to the product developed as well as the overall coherence of the project with professional responsibility.

Evaluation
Evaluation is based on the final sustainability report that constitutes the common deliverable related to module C activities for all INGENIA courses. This report is evaluated by the module C instructors and it represents 12.5% of the final score of the INGENIA course. Total score is computed from two separate scores assigned to the ethical & social issues and environmental assessments within the sustainability report. The evaluation is based on a rubric included in the teaching guide that was designed taking into account the expected global outcomes of the Master Degree. The rubric includes indicators and minimum performance criteria regarding knowledge, application and integration of sustainability concepts.

RESULTS AND DISCUSSION

Some examples regarding the discussion on relevant social issues, environmental life cycle assessment flowchart and quantitative analysis, taken from the sustainability report are shown in
Figure 5.

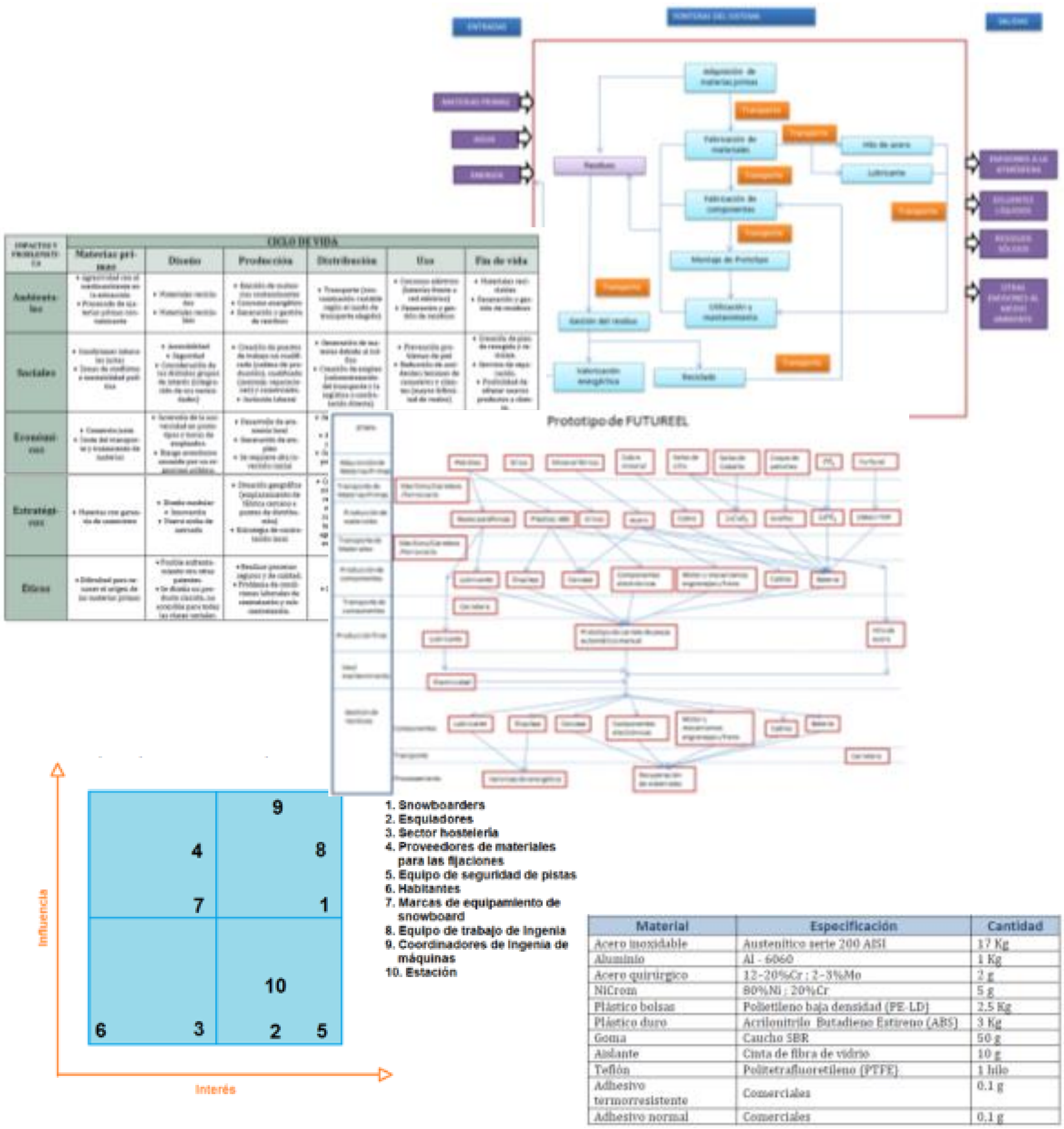

Figure 5. Excerpts from students' sustainability reports

The projects developed during the courses 2014-15 and 2015-16 were:

- Automatic bag dispenser for fruit and vegetables at supermarkets
- Electronic fishing reel
- Smart coin purse

- Flabellum umbrella (automatic sunshade)
- Automatic pill dispenser
- Bindboards for snowboard

The products the students are working on this year (2016-17) are:

- Automated drink mixer and dispenser
- Mechanically-aided shopping trolley bag
- Disinfector for electric toothbrushes

Module C scores have been found to improve substantially, from an average of 6.5 in the first course edition to 8.1 in the second one. The corresponding scores regarding the ethical & social and environmental assessments were 6.3 and 6.8 in the course 2014-15 and 8.2 and 8.0 in the course 2015-16. Beyond module C scores, results of the INGENIA courses from the two first years (those of the current one are not available yet) have been analyzed from four perspectives: conceptual, methodological, students' satisfaction and sustainability skills. Qualitative information has been obtained from classes, focus groups with professors and final reports prepared by students. Quantitative data was gathered from pre- and post-questionnaires with closed and open questions provided to students.

The conceptual perspective is related to the theoretical dimensions of sustainability for the INGENIA "Product development" course. For the sustainability methodology is very important the identification of stakeholders and materiality regarding the sector where students are involved. The relevant issues that have emerge are shown in Table *2*:

Table 2. Most relevant sustainability issues highlighted by "Product Development" students

Device	Year	Ethical, social issues	Environmental issues
Supermarket bag dispenser	2014-15	Labor market implications, sustainability awareness	Plastic (PE-LD) savings; energy consumption during operation
Electronic fishing reel	2014-15	Labor market and regulation implications, boost of fishing demand	Ecotoxicity related to Li-ion batteries and after life waste management
Smart coin purse	2014-15	Help for the elder and disable people	Recyclability of raw materials, impact of electronic components and batteries
Automatic sunshade	2015-16	Labor risks and social responsibilities in new mechanism with additional complexity. Potential ethical issues.	Consumption of materials and responsible suppliers. Electricity consumption. Potential air cleaning applications.

Automatic pill dispenser	2015-16	Design for social need integrating all stakeholders view	Product design with low environmental impact criteria: raw material recyclability. Energy consumption.
Bindboards for snowboard	2015-16	New health security risks. Design “for all” criteria (accessibility).	Environmental implications of raw materials (plastics/metals). Indirect environmental impacts derived from ski.

During these two years, we have been able to discover that, even with a common framework to integrate sustainability into INGENIA “Product development” course, differences of use among the designed devices, made the sustainability agenda quite different for each group. Although the methodology presented was flexible enough to be applied to any kind of project, we noted that the most challenging scenario relates to devices oriented as consumer goods, without any specific orientation to cover basic social or environmental needs. Methodological considerations to adapt the general INGENIA sustainability framework to the “Product development” course, try to solve the mentioned conceptual challenges. The links between sustainability framework and product development methodologies must be reinforced. The identification of stakeholder needs and definition of the LCA flowchart are key issues to build these links.
The results of the evaluation of questionnaires of students’ satisfaction show that the efforts to find a smooth way to introduce sustainability in the “Product Development” course has been perceived. Table 3 summarizes the main results and shows that the assessment of most of the items related to module C have a positive trend. Information from the questionnaires of the first edition were essential to improve our approach to sustainability within the course. In the last year further modifications were made to improve issues such as documentation, guidance and sustainability contents in moodle.

Table 3. Summary of students’ degree of satisfaction degree of satisfaction - from 0 (worst) to 5 (best)-

Assessment of module C-related items	**2014-15**	**2015-16**
“Product development” sustainability specific sessions	3.00	3.59
Sustainability professors	3.69	3.68
Inputs for sustainability from INGENIA professors	2.92	3.74
Sustainability contents in moodle	3.00	3.03
Sustainability methodology	3.38	3.91
Evaluation criteria through students works	3.42	3.62
Global	3.19	3.59

The final objective of the sustainability activities included in the CDIO course INGENIA is to teach sustainability skills to the students. The data available of the outcome evaluation are common for all the INGENIA courses, and there is not specific analysis for the “Product Development” course. From the data gathered for the 2014-15 course (Miñano et al. 2016), can be pointed out that INGENIA courses made students more aware of ethical and social impacts, compared with the initial perception of only environmental ones as relevant. Particularly students improve the self-perceived ability to analyze social impact and the capacity to enhance the positive impacts of an engineering project. Although students have stronger fundamentals regarding environmental issues since they have a common specific course during their previous degree (Borge et al., 2011), INGENIA also helped them to gain a better understanding of environmental implications under a wider, life cycle perspective.

CONCLUSIONS AND LESSONS LEARNED

A methodology to include environmental, social and ethical impacts was developed and successfully implemented to the “Product Development” course. This methodology is derived from the common framework defined to incorporate sustainability into INGENIA CDIO courses but it is specifically integrated with the teaching planning and methodological approach (product planning, concept design phase as well as basic and detailed engineering stages) of the course. We found that the identification of stakeholder needs and definition of the LCA flowchart are key issues for a successful integration of sustainability in the conception and implementation of any product.

Both, final scores and students questionnaires point out that this methodology is useful to integrate sustainability in this course, although there is a need for specific adaptations to tailor the methodology for each product. In the future this methodology may be further refined and improved by analyzing stakeholders and materiality related to each specific project so more systematic and meaningful indications and orientation can be provided depending on the type of product being developed. The integration of sustainability has focused so far on the Conceive and Design stages of the course, since as stated before, this is the key for a sustainable product. Nonetheless, options to incorporate social, ethical and environmental criteria into de Implement and Operate stages should be also addressed in the future for a more holistic approach to sustainability within the course.

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