"ENGINEERING DESIGN" COURSE TRANSFORMATION: FROM A CONCEIVE - DESIGN TOWARDS A COMPLETE CDIO APPROACH

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ABSTRACT

"Engineering Design" is a discipline aimed at improving our understanding about the development processes of novel and successful products, processes and systems in general, and at providing engineers with methodical steps for enhancing such processes. It may well be the engineering discipline more linked to the CDIO approach and to the conceive-design-implement-operate process. The benefits of applying "Engineering Design" principles are better appreciated when facing the development of complex systems. In the field of Mechanical Engineering some of the more complex systems an engineer can develop are advanced mechanical systems and machines.

In this study we present the transformation process of an "Engineering Design" course, carried out in parallel to the implementation of the new Master's Degree in Industrial Engineering at ETSII – TU Madrid. In the old Industrial Engineering plan of studies, implemented in 2000, the "Engineering Design" course was taught in the 5th academic year for Industrial Engineering students specializing in Mechanical Engineering and lasted for one semester. In the new Master's Degree in Industrial Engineering, which started in 2014-2015, the "Engineering Design" course is taught in the framework of a School-level project-based learning initiative and can be chosen by students from all Industrial Engineering specializations. The new subject lasts for two semesters and it is taught, in the 1st academic year of the Master's Degree, to students having finished a four-year Bachelor's Degree in Industrial Technologies. When transforming the course, our first aim was to let students live through a complete CDIO process, as having a two-semester structure gave us additional time for reaching the implementation and operation stages. With the old one-semester structure they could just focus on the conceptual and design phases. With the new approach their experience is more complete but several challenges arise, which are systematically analyzed in the following pages. A comparative study, taking account of the opinions of students and teachers is also presented and helps to support the benefits from complete CDIO experiences. Key aspects, including: student motivation, coordination between teachers, supervision of the projects under a tight schedule, rapid prototyping resources for reaching the implementation and operation stages, among others, are discussed and the more relevant lessons learned and proposals for improvement are put forward.

To our knowledge it constitutes the first subject following a complete CDIO cycle in the field of Engineering Design applied to machines engineering in our country.

KEYWORDS
CDIO as Context, Integrated Curriculum, Integrated Learning Experiences, Active Learning, Engineering Design, Mechanical Systems, Machines Engineering.
(Standards: 1, 3, 5, 7, 8).

INTRODUCTION. THE EVOLUTION OF THE SUBJECT FROM A CONCEIVE-DESIGN TO A COMPLETE CDIO APPROACH.

"Engineering Design" course is being taught at the UPM Mechanical Engineering Department in the TU Madrid School of Industrial Engineering since the 2004-2005 academic year (Munoz-Guijosa et al., 2011). From its conception, in the framework of the Bologna curriculum philosophy, it was designed as a Project-Based, 6 ECTS, 5th year capstone course, in which students integrate the knowledges already learned and also develop professional skills (Díaz Lantada et al., 2013), (Schuman et al., 2005). Until 2014, students were instructed to perform the first development stages –product planning, concept design, basic and detail engineering- of a product selected by themselves. Deliverables included market study, patent analysis, business plan, technical drawings, assembly procedure, customer information, maintenance plan, risk analysis and a report in which students should also demonstrate the application of different design rules as safety, clarity, recyclability or aesthetics.

In 2014, the "Ingenia" initiative was launched at the School of Industrial Engineering (Hernández Bayo et al., 2014), through which the 1st year Master students must dedicate 12 ECTS to the complete execution of an engineering project in a CDIO-based course. 5-hour classes are taught every Monday. Nine courses were offered to the students in this initiative in the 2014-2015 academic year. In present year, students could select one out of eleven "Ingenia" subjects. Table 1 shows the subjects participating in the initiative.

As the course length is doubled, the inclusion of "Engineering Design" in the "Ingenia" initiative has permitted us to extend the scope of the development up to the prototype manufacturing and testing, in a complete CDIO experience (Chacón et al., 2015), (Crawley et al., 2007). We have also had the opportunity of sharing experiences and knowledges with our colleagues in other "Ingenia" subjects for continuous improvement, as well as dedicating a subject-specific budget for the execution. Presently, the "Engineering Design" course is the third most selected by students.

Table 1. Available "Ingenia" courses in the 2015-2016 academic year

Structural optimization based on modal analysis-adjusted FEM models
Industrial plant projects development and management
Bioengineering
Engineering Design
Automotive Engineering: Formula SAE
Products for everyday life
Systems engineering
Videogames design
The School of the future - Smart ETSII
Electrical systems design ("Ingeniando" un sistema eléctrico)

At the course beginning, students form 6-people teams, and think about different products to propose to the class. A product proposals presentation is carried out during the third week, in which students must convince their colleagues about each proposal benefits and novelty. A voting is then carried out, in which three to six products are selected for the development during the rest of the course. During the conceive stage, students study the potential market, comparable products functionalities and prices and existing patents. They also design and execute surveys through which more than 100 people is asked about desired functionalities. As a result, they design a product definition and a business plan which must guarantee an internal return rate greater than 20%. During the design stage, students create different concept alternatives, and select the most promising ones for the basic and detailed design stage, in which they design or specify the necessary components. In the implementation stage, during which students manufacture a complete, functional mechatronic prototype, they must source commercial parts from different international suppliers, dealing with price negotiations and billing and logistics management, as well as manufacture the specific parts, for a subsequent integration and assembly. In the operation stage, they create and execute a testing plan, redesigning the product if some test is not passed. Packaging and advertising must also be designed and executed. Finally, students must prepare a multimedia presentation for a specific Ingenia event. As sustainability is one of the most important drivers on the engineering education philosophy of our School, it is considered during the whole development experience, not only at product level, but also regarding the complete lifecycle and involved socioeconomic agents.

Figure *1* shows the course planning. Despite we try to maximize the time students devote to the product manufacturing and testing, product planning and design, CAE, theoretical and specialized classes, as well as evaluation must also be performed. We consider the credit distribution showed in the figure as a good balance between all the course activities.

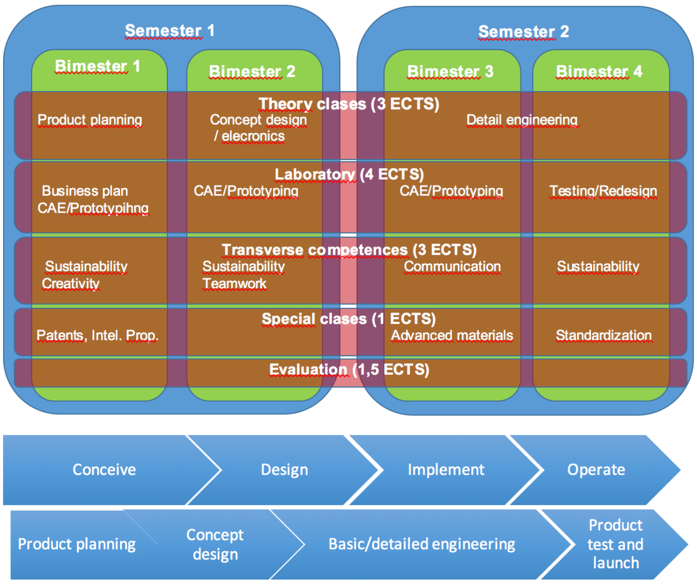

Figure 1. Course planning

CRITICAL ISSUES IN THE IMPLEMENTING OF THE COMPLETE CDIO APPROACH.

In the one and a half courses we have already lived in the “Ingenia” experience we have had opportunities of talking with colleagues and teachers of other “Ingenia” subjects, students and other focus groups, as well as thinking about the course performance. This has allowed us to detect some factors that have to be carefully considered when planning and executing it. We hope these thoughts can be useful to other colleagues involved in the design and execution of CDIO-based courses.

Laboratory, creativity, IT and other resources

A strong laboratory and IT capacity is needed (Table 2) in order to fulfill the requirements arising in every project phase, but specially during the implement and operate stages. During the conceive stage, students must gather a vast amount of information related to the novelty of each product proposal, the state of the art, comparable products –including their specifications, prices and sales volumes-, potential market and market segmentation. This includes the use of patent and article databases and statistical modelling programs for the analysis of the surveys results. The business plan design involves the use of Montecarlo simulators for financial risk analysis. Likewise, the use of creativity tools during the concept design stage implies the need of brainstorming materials, solid modelling systems and rapid prototyping tools for students anytime along the whole day schedule. In the develop stage, mechanical and thermal FEM calculations are to be performed, which implies the use of CAE systems with those capabilities. Electronics development tools are also needed for the design of the product control and monitoring systems. For all the above tasks, we have configured an IT room with 15 computers managed by our IT technician, which is open from 9:00 to 18:00 every weekday. During the implement stage, harder laboratory resources, as lathe, mill or drill machining, solvents, resins and other dangerous products or processes handling, or the use of sensitive laboratory equipment - we will additionally use autoclave and other composite manufacturing tools next year- makes the contribution of professors and specialized laboratory personnel necessary. Finally, testing and data acquisition and analysis systems are required during the operate stage. Students must perform static and dynamic mechanical and thermal tests and measure the product response, as well as product fatigue performance. For accomplishing this, testing equipment and materials as traction-compression devices, fatigue bench, accelerometer, modal hammer, thermography camera, thermocouple, strain gauges are available, along with a data acquisition system and data analysis tools. Once again, the participation of professors or laboratory personnel is needed in order to guarantee the system integrity and adequate operational results. We have also reserved a workshop-type room so that students can work during the concept design and basic engineering.

Financing

A financial support must be available not only for the course preparation, but also for a long term subject sustainability. We take advantage of different assets already available at the machinery engineering division at UPM, used for different research projects and industry consulting works. An initial amount of approximately 4000€ was employed for the acquisition of the fixed assets that were not available at the laboratory. A yearly amount of approximately 4000€ is needed for the maintenance of the CAE licenses, as well as the purchase of the fungible materials for the year products. A substantial part of this amount is financed by the “School Friends Society”, which encompasses different companies where alumnae hold relevant positions. The maintenance of other computer programs and databases is held by the University or the Machine Engineering Teaching Group.

It is straightforward to think in a possible resource sharing between the different departments involved in this CDIO initiative. However, this may not be a working idea, taking into account the total amount of students involved in the course, about 250, which is hardly compatible with the normal department activities, personnel and workload. Specific collaborations are however kindly carried out when highly specialized problems appear during the development.

We are evaluating the use of sponsoring as an additional financing alternative, in the same fashion as the management of the industrial chairs and sponsored rooms. Despite its many advantages –for instance, not only financing is obtained, but also long term relationships with employers and technology transfer activities and research topics creators-, care must be taken for avoiding the possible reduction in the range of products which could be developed during the course because of restrictions established by the sponsors.

Assistant students

As in the prior, CD based course students did not value extra, out of class guidance, additional support is very well welcomed by the students in the IO stages our new subject includes. From our experience in other project-based subjects as “Machinery Elements Design II”, we are aware of the added value assistant students give to the class and out of it. We select one or two students for each academic course. They are selected from the prior course, so they have already lived the whole development process. Consequently, they know where the critical points are and help students in overcoming them. Furthermore, they establish a close relationship with the students and gather valuable information about the team evolution, conflicts and specialized learning needs. Students are prone to integrate them in the social networks and webtools (mainly WhatsApp, Dropbox, Google Drive and Google Calendar) they create for the subject, so information about potential needs can be processed in advance. As a selection criterion, we overestimate the electronics design application knowledge, provided that this is the area where mechanical engineering students have normally less experience. The assistant students normally take part in a special, school level program for earning up to three free configuration credits, and have a small economic reward financed by our group.

Table 2. Assets and fungible materials needed for the course

		Item	Financed by
Assets	Fixed	Laser stereolithography system	Other projects
		Vacuum casting system	Other projects
		Oven	Other projects
		Composite autoclave	Other projects
		Composite vacuum system	Other projects
		Lathe, mill, drill	Other projects
		Welding system	Other projects
		Traction-compression machine	Other projects
		3D microscope	Other projects
		Sound power and intensity meter	Other projects
		Termography camera	Other projects
		Accelerometers	Other projects
		Modal hammer	Other projects
		Data acquisition system	Other projects
		Hand tools	Other projects
		3D Printers	UPM-Ingenia
		3D scanner	UPM-Ingenia
		Power sources	UPM-Ingenia
		USB oscilloscopes	UPM-Ingenia
		Mini fatigue machine	Other projects
		Multimeters	UPM-Ingenia

		Item	Financed by
Assets	Current	Catia	DIM
		Unigraphics	DIM
		Solid Edge	Student version
		Matlab	UPM
		SPSS	UPM
		Crystal Ball	DIM
		Journal suscriptions	UPM
		Computers maintenance	DIM
		Electronic development platforms	DIM
		DC motors	UPM

	Item	Financed by
Fungible materials	Resins	UPM-Ingenia
	Photopolymerizable resin	DIM
	Silicons for vacuum casting	DIM
	PLA and other plastics for 3D printers	UPM
	Strain gauges	DIM
	Electronics materials (displays, switches, LEDs, sensors, buzzers, servomotors, diodes, resistors, coils…)	UPM-Ingenia
	Electric materials	UPM-Ingenia
	Cardboard	UPM-Ingenia
	PC or metacrylate panels	UPM-Ingenia
	Product specific fungibles	UPM-Ingenia
	Hardware (screws, nuts, flanges, bars, cables, gears,…)	UPM-Ingenia
	Glass, carbon fiber	DIM

Skills evaluation system

In the prior CD course, limited to the detailed planning and design of a novel product, evaluation was done with respect to technical criteria, as well as creativity and communication competences. As in the present CDIO course students have the opportunity of acquiring additional competences by reaching the final stages of implement and operate that novel product, not only a deeper evaluation accuracy can be reached, but also a wider field of competences can be evaluated. Regarding the number of competences evaluated, we have added “commitment to continuous learning”, and “teamwork”: in the prior CD course, student teams could easily split in different isolated subteams for the product design, provided that the interrelation level could be minimized by themselves, overcoming problems related with system integration. On the other hand, in the new course strong issues regarding teamwork appear in the implementation stage, due to the fact that students must construct a real working system, so integration is mandatory. Furthermore, in the same stage, students must deal with technical and commercial information provided by different suppliers, which force them to study some engineering concepts in a deeper detail with respect to what they learned in prior subjects. In the operate stage, different design and integration problems appear, which force students to redesign and face new teamwork and tight schedule working challenges. As a result, the new competences are now also evaluated by dedicated rubrics for team measurement and a 360º student evaluation for student teamwork performance measurement, where student behavior, compromise, goal fulfillment and workload are evaluated by the rest of the team members as well as by the teachers. In the implement stage,

With regard to evaluation accuracy, we have improved the use of evaluation rubrics: as a result of a task force composed by different UPM professors, we have developed up to six rubrics which allow for the measurement of the competences acquisition level in a four-level scale. As an example, Table 3 shows the rubric corresponding to the evaluation of the “creativity” competence acquisition level.

Table 3. Rubric to evaluate the “Creativity” competence

Indicator	Evaluation level: D	C	B	A
Number of different approaches or solution alternatives proposed.	Student is not capable of designing a valid approach.	Student provides at least one valid approach or solution alternative.	Student is able to create different approaches.	Student is able to create different approaches and solution alternatives.
Originality degree of those approaches or solution alternatives.	Proposed alternatives are frequently found in the reference group.	Proposed alternatives are sometimes found in the reference group.	Proposed alternatives are seldom found in the reference group.	Proposed alternatives are not found in the reference group.
Effectivity, feasibility degree of those approaches or solution alternatives.	Proposed alternatives do not solve the problem, are not a correct approach, or are not feasible with real world restraints.	Proposed alternatives do not solve the problem in an efficient way, or imply feasibility issues.	Proposed alternatives solve the problem in an efficient way.	Proposed alternatives solve the problem in an efficient way and do not create subsequent problems.

Individual and overall evaluation system

Due to the considerations explained above regarding number of students and limited budget, students must be grouped in big teams (6-12 people each, see “large groups management” section below). This fact eases the possibility of strong performance and learning divergences between each team member. In addition to the 360º student evaluation described above, we ask students to carry out individual works related to some lessons learned in different stages: application of different creativity methods to the solution of a problem and application of basic design principles to a simple problem. Furthermore, we nominate four task managers every two weeks in each team for the management of subteam works, and check if the assigned task was completed at the assigned deadline. Task manager selection is done according to each student’s major. However, in some cases, specially regarding electronics, the management role must be taken by the same person in different periods. Finally, we do not allow students to select who will carry out the follow-up presentations, so all team members have to prepare them.

Table *4* shows the evaluation scheme followed during the 2015-2016 course. We try to balance the weight of team and individual performance, as well as the weight of technical and professional competences.

Table 4. Evaluation scheme

Group evaluation (55%)								
Presentation 1 (product planning) (10%)		Presentation 2 (concept design) (10%)		Presentation 3 (Final design, packaging, advertisement) (15%)	Product performance (35%)	Teamwork (15%)	Creativity (10%)	Self learning (5%)
Small group (35%)	Big group (65%)	Small group (35%)	Big group (65%)					
Individual evaluation (30%)								
Work 1 (creativity tools) (20%)	Work 2 (application of basic design	Teamwork (20%)	Task management (20%)	Presentations (20%)				
Sustainability (15%)								

Teachers' coordination

The most remarkable organizational change we have faced is the increase in the lab personnel workload during the implement stage, as students require the use of the rapid prototyping facilities. Several rules must be given to the students in order to not overloading the facilities, as completing a Google Calendar and requesting teacher permission for 3D-printing –students tend to study the design performance in the 3D-printed prototypes instead of using the CAE systems, so there is a quite high risk of 3D-overprinting and consequently of resources waste-. We have also redistributed each teacher's workload, taking into account that several (up to four) teachers may be present at the same class in some key sessions (product proposals selection, concept selection, design freeze, final products presentation). We have experienced an increase in tutoring sessions request, which are frequently group sessions. As a result, we have set a fixed, 3 hours weekly tutoring session in addition to the regular class. This also implies an additional workload redistribution.

Teachers and assistant students training

Prior to the first complete CDIO course issue in 2014, a pilot development was carried out by teachers and selected assistant students in order to evaluate the student necessary working load, course planning and additional material and teaching resources needed. A self-powered trolley with connection to smartphone, which was one of the products designed in the last issue of the prior CD course, was selected as a representative example. Through the work, we issued the list of the estimated electrical and electronic equipment and materials needed for the course, created an electronic development 5-hour course and its documentation, and adjusted the course planning and student organization and roles.

CRITICAL ISSUES IN THE EXECUTION OF THE COMPLETE CDIO APPROACH.

As the map is not the territory, care must be taken to the field problems appearing during the subject execution. Environment variables as student high workload, students number and heterogeneity, limited resources and student attitudes can give rise to serious problems for obtaining the planned teaching outcomes. We have detected four main fields to take care to: relationship with students, selection criteria for the products to be developed, large groups management and student motivation.

Diffusion activities. Student selection. Success celebrations.

We have experienced the powerful influence "official" results presentation to different focus groups (students, teachers, companies, prospective students) has on the students' motivation as well as the prospective students' recruitment. On June 7th, 2015 a presentation event was held at the ETSII conference hall (Figure *2* (a)), in which multimedia assisted oral presentations were performed for each developed product in the eight Ingenia subjects taught during the 2014-2015 course. Afterwards, poster and product presentations were performed in several stands at ETSII main hall (Figure 2 (b) and (c)). Knowing the need of such a presentation in advance meant a fixed deadline and encouraged students to finish the product in time, and to prepare excellent marketing presentations and pitches. Prospective last year undergraduate students were impressed about the experience their colleagues lived in the subject. Additionally, the subject and the results of the 2014-2015 course were presented to the prospective students in an information event on September, 7th 2015. This increased the number of candidate students from 30 in the 2014-2015 course up to 60 in the 2015-2016.

Celebration of success is a key activity in any high performance team. We believe in this, and explain it to the students in the teamwork classes. A success celebration party was held after the demonstration (Figure *3*), where students and teachers had the opportunity of interchanging experiences regarding a full academic year relationship. Such an activity also brings teachers a wider insight about possible improvements for subsequent courses.

Figure 2. (a) Products presentation in the Ingenia results presentation event. (b), (c), Product demonstrations at the ETSII main hall.

Student selection is also a key issue for the course success. In addition to high academic levels, we try to keep a high heterogeneity in terms of student major –specially trying to include some electronics and automation students- and degree institution –trying to include some students coming from institutions different to TU Madrid-. Table 5 shows the composition of the 2015-2016 course groups. Even though no instructions are given to force students to keep heterogeneity, it is spontaneously created by prior student relationships. Motivation is also taken into account, and students which asked for their participation prior to the official course opening date and fulfilling the grade level and course selection requirements have a special consideration.

Figure 3. End of course party

Table 5. Groups composition by student major

GROUP NUMBER	PRODUCT	Machinery engineering	Electrical engineering	Electronics engineering	Industr. org. engineering	Energy engineering	Materials engineering
1	Automatic sunshade	10	1	1	1	0	1
2	Automatic pill dispenser	7	0	3	4	0	0
3	Unlockable snowboard binding	6	3	0	1	3	0

Product proposals evaluation

We are amazed about the amount of proposals the students provide in the proposals presentation class. A total of 80 product proposals have been presented for voting in the 2014-2015 and 2015-2016 courses, which means an average of 6 proposals per team.

Most of the product proposals show an impressive creativity and novelty, however also having a high pragmatism level at the same time, which demonstrates the underlying product planning work performed by the students as well as their high technical background. Being all the product proposals great, not all of them are suitable to be used for a complete CDIO experience with a success guarantee in the development during the course and consequently measurable results in skills acquisition. Hence, and a careful selection must be done for deciding the products to develop during the course. This fact has narrowed the scope of selectable products with respect to the prior CD courses.

Several criteria are to be used for the selection, in order to maximize the success probability at the end of the course:

- *Novelty*: students are noticed to perform patent searches in order to be able to propose products that are not in the market. The innovation may not be radical, but must be at least incremental. A new functionality is at least expected in each product proposal.
- *Student motivation*: for not reducing the number of proposals and trying to give rise to as much proposals as possible, students are instructed to look for any idea they may already have. Many students have product ideas since they were much younger, but they did not feel they were prepared to develop them. The environment created in this course (teamwork, teachers' help, lab facilities and other resources) motivates the students to take advantage of the opportunity.
- *Multidisciplinarity*: as the course is also planned as a capstone activity, where students integrate and develop the skills learned in prior ones, and the develop of teamwork and complex problem solving competences is expected, sufficient degree of multidisciplinarity is required for a product proposal to be selected. This includes the existence of at least two different energy domains. Most of the proposed products include mechanics and electric/electronic domains, having others also thermal or fluidic ones.
- *Budget*: as a budget limit exists for each product, only a limited number of products can be developed. Consequently, a tradeoff must be established between the number of products developed (which in turn must be coherent with the number of students and student teams) and the level of development of those products. In our course, which is the one most selected by the students among all the "Ingenia" course proposals, the number of students is about 40 and our yearly budget for current assets and fungible materials is about 4000€ per course, so we have chosen to develop three different products per year, having each one a budget of approximately 1000€ for fungible materials.
- *Obtainability with available resources*: for a proposal to be selected, the operations involved for the development must fit into the department available resources. Alternatively, the proposal may also be selected if the operations that cannot be performed at the own facilities can be subcontracted at acceptable cost and lead time.
- *Coherent student workload*: the student workload involving the product development must be carefully checked, taking the experiences gathered in prior courses as a measurement basis, so product proposals involving neither excessive nor insufficient workloads can be rejected. Factors as number of possible design alternatives available if the main one fails, necessary theoretical and numerical calculations, estimated number of prototypes necessary for obtaining a fully functional one, number of parts or number of parts suppliers needed must be carefully taken into account. Sometimes, the workload estimation initially taken into account to select a proposal can differ from the actual workload actually measured at midcourse. In such cases, students may be instructed to develop two different concepts for the same product idea, or reduce the number of functionalities.

Large groups management

Due to the need of creating teams of up to 12 members for the products development, we have developed different strategies in order to correctly distribute the workload and responsibilities. A strategy that is being successful is the creation of “teams” and “subteams” for the products development: at the beginning of a stage, work regarding each product is assigned to two “subteams” of 5 to 6 people, which must create and present solution alternatives in the next class. Once the two subteams working in the same product have presented their solution alternatives, a discussion is carried out to find out the best ones, as well as the possible improvements which can be performed in them. Then, subteams are joined in a 10-12 people team which must develop those best solutions and present them in the next class.

Role play is also needed in order to equilibrate student workload. From the basic design stage, students belonging to each team are grouped according to the different functional positions needed: electronics and testing, mechanics and materials, system integration, purchase and marketing, and project management.
Finally, we encourage students to assist to the extra tutoring class held every Thursday – at least two students must assist to this class-, and Google Calendar and Google drive are used for laboratory resources management and the archive of an open points list for each product.

Student motivation

In the two courses experience we have so far, we have noticed several student concerns about the feasibility of finishing the product in time and under the specification and budget restrictions. Their workload is intense not only because of our subject, but also because of the other ones they must also work in, so they are exposed to constant stressing situations. One important task for the teachers and assistant students is to constantly encourage them for a positive attitude, and let them be aware of the potential they already have due to the competences they acquired in prior courses, as well as letting them know the help the teachers and assistant students are willing to give. We also plan a former students presentation in the second class, so that the course students can assess the expected deepness and check that finishing the product in time, budget, quality and schedule is possible. In this presentations, we highlight examples of products that have been patented by the students, or obtained an interest by external companies. We think the example given by the teachers in the everyday classes is also very important. Most of the teachers have industrial, patents and/or spin-off experience, so an entrepreneurship environment is created. All these efforts are also effective for shifting the “study to pass the subject” attitude some students still keep to the “study to learn” attitude.

FIRST AND PRESENT COURSES RESULTS

Figure *4* shows different development stages of an automated fruit bag dispenser for supermarkets, which allows customers to select bag size and delivers bags already open. This product was developed during the 2014-2015 course. Figure 5 shows an automated fishing rod, also developed during the same course, which eliminates the “boring” time (according to professional fishers) elapsed from lure throw until fish bite by creating an automated lure movement. 3 programs are available for simulating 3 different lure behaviors. The product detects the bite and stops working, so that the fisher can take over control. Regarding the 2015-2016 course, we supply some pictures of the development stage as of the contribution submission date (February 2016). Figure *6* shows two concept alternatives for an automated pill dispenser, that is being developed during the present course, as well as a general product concept. The figure shows as well two concept alternatives for a snowboard boot fixing system with an additional quick release function.

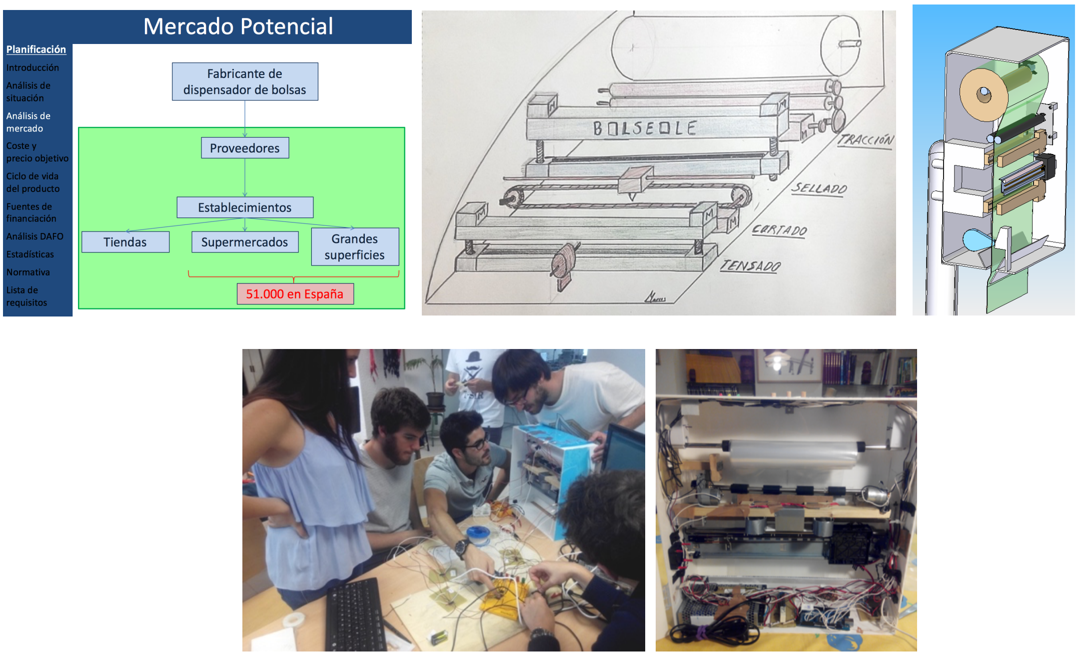

Figure 4. Different stages of the complete development of an automated bag dispenser: product planning, concept design, basic engineering, prototype manufacturing, prototype testing.

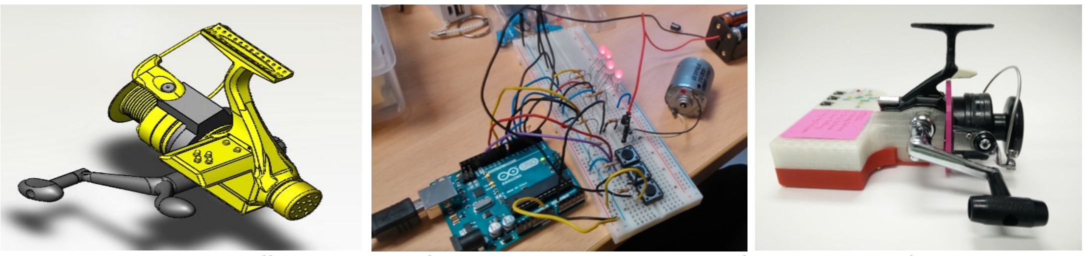

Figure 5. Different stages of the complete development of an automated fishing rod.

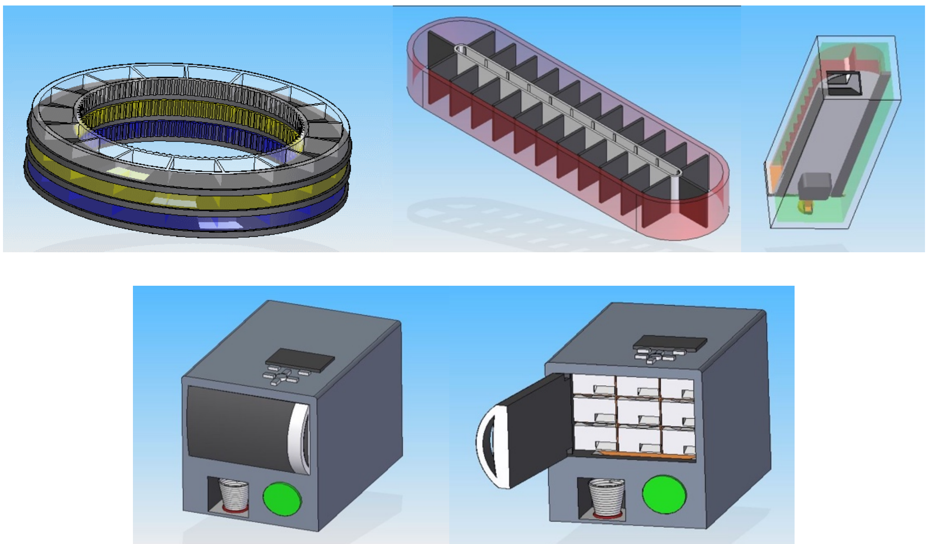

Figure 6. Different concept alternatives for pill+blíster management in an automated pill dispenser in present year course. Selected product concept alternative.

IMPLEMENTATION ASSESSMENT

Due to the fact that the 2014-15 course was the first one in which the complete CDIO approach was executed, limited information is available for assessing the success of the implementation. However, student surveys and competence evaluation results can serve as estimators of the first year performance. Figure 7 shows the results overview of the student survey. The overall impression is quite good. Regarding the acquisition of professional competences, “strategic analysis”, “planning”, “implement” and “continuous learning” competences are well valuated by the students.

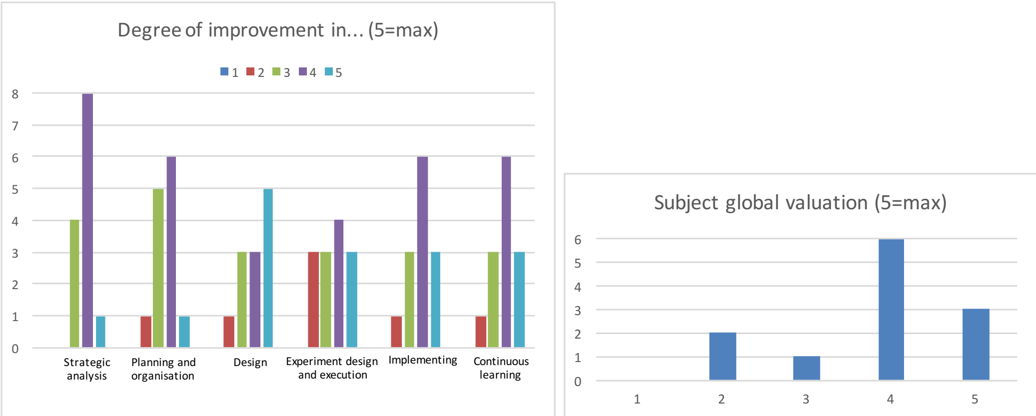

Figure 7. Results of the 2014-2015 student survey.

We are proud of one of the most frequent responses of our last course students: after the course, they feel capable to make their ideas come true. This is a very good overview of the learning outcomes, and the best argument for convincing the next year students to choose our subject. Students also highlighted the opportunity of integrating all the knowledges studied in other subjects, and the experience with real life problems related to tight schedule and budget, unpredicted errors, relationship with suppliers and invoicing. On the other hand, they feel that less theoretical classes should be given, and that the implement and operate stages should begin before. This year, we have advanced the beginning of the implementation stage one and a half months and moved some theory classes, so that they can be given at the same time students are working on their prototypes, and we asses that the knowledges to be given are necessary.

CONCLUSIONS. LESSONS LEARNED.

“Engineering Design” has been transformed in a complete CDIO experience in which students live the complete development process of a product which they propose. The results obtained during the last academic year, with respect to evaluation results in competences acquisition and student opinion are very good, as well as the course flow in present year. In the limited experience -one and a half courses- encompassing subject design, implementation and execution we have found several key issues for its success. Financing, human resources management, including teachers’ coordination and teachers and auxiliary personnel workload increase, lab facilities, evaluation scheme design and assistants and teachers training are the most important areas to handle during the subject planning. Student selection, activities diffusion, product selection and large groups management are the most important activities to care during the execution. Constant student motivation and support is mandatory for teachers, assistant students and lab personnel in order to convince students about the possibility of finishing the development in time, specification, budget, quality and schedule. The results of this effort are clearly detected in student motivation, self-potential awareness and attitude towards the subject. This subject is also being a great experience for teachers, giving us the opportunity of learning new things regarding teaching, product development and student behavior. The relationship established between students and teachers, who live the experience together, enriches both groups and is frequently extended to subsequent subjects during the master second year and the master thesis.

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