DESIGN OF THE ADVANCED ENGINEERING PROJECT COURSE FOR THE THIRD YEAR OF ELECTRICAL ENGINEERING AT TELECOM BCN

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ABSTRACT

The Advanced Engineering Project is the third of four steps in the design-implement subjects path of the Telecom BCN curricula. The first and second steps, the Introduction to Engineering subject and the Basic Engineering Project subject were described in the two last CDIO Conferences. The first year subject [1] includes a partially guided project through a complex system, but with low technical difficulty. The second year project [2] has a higher technical difficulty and emphasizes the modular structure of complex ICT systems, although a working team only develops one of the system blocks. In the third year course, Advanced Engineering Project, AEP, which is described in this paper, larger working groups should conceive, design, implement and operate a whole system including its business plan. During the fourth and last year, the individual students join a research department or company to perform their final thesis. The AEP topic is specific for each degree (electronics, networks, audiovisual systems and communication systems), is performed by larger teams (9-12 students), and each project is unique. The product or system to be designed and built in AEP should be complex enough to need its breakdown in 3-4 subsystems. Then, 3-4 subteams of 2-3 students design, build and test their specific subsystem and integrate it with the others in order to complete and test the full system. The course has 12 ECTS credits which means 300 h of workload per person along the semester (15 weeks). The main part of this time is devoted to autonomous work, but the students also attend to seminars (2 hours per week) and have supervised attendance to the lab 6 hours per week. There are short seminars (system thinking, intellectual property rights, patent search, team work, …) and longer seminars (several sessions) on how to prepare a business plan. The two projects developed this year with the pilot group have been a picosatellite (CubeSat) and a system to obtain a map of the acoustic response of a room.

KEYWORDS

Design-build course, Electronic Engineering, Audiovisual Systems Engineering, Project-based Learning.

INTRODUCTION

The Advanced Engineering Project is the third of four steps in the design-implement path of the Telecom BCN curricula. The first and second steps, the Introduction to Engineering subject and the Basic Engineering Project subject were described in the two last CDIO Conferences. The first year course has an Introduction to Engineering course which includes a partially guided project through a complex system, but with low technical difficulty. The second year project has a higher technical difficulty and emphasizes the modular structure of complex ICT systems, although a working team only develops one of the system blocks. In the third year project (Advanced Engineering Project, which will be explained with detail in this paper), larger working groups should develop a whole system, including its business plan. The fourth and last year, the individual students join a research department or company to perform their final thesis. All project subjects are located on the second half of each year. Figure 1 shows the evolution of the trade-off between the projects breadth and depth along the project course path.

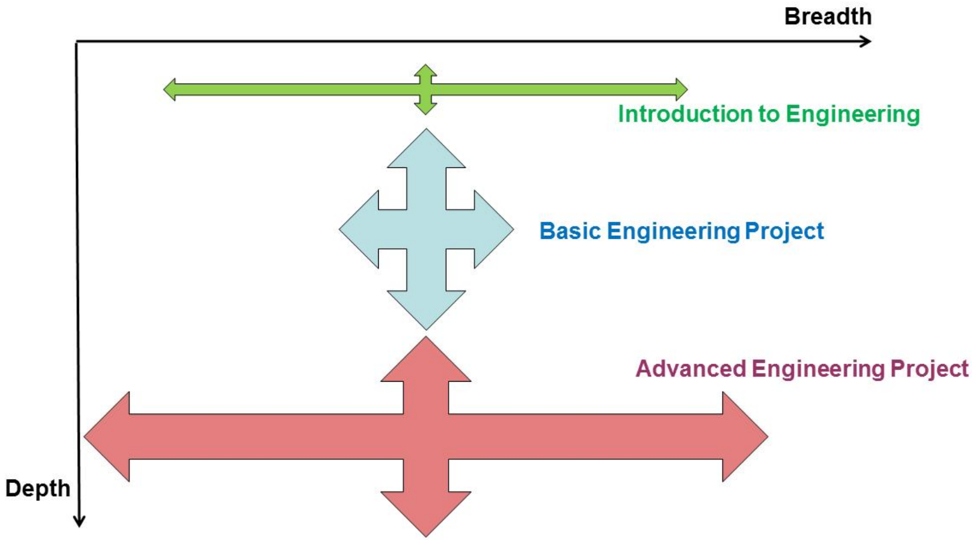

Figure 1. Breadth *vs* depth map of the project subjects of the first three years

Telecom BCN, the Electrical and Telecom Engineering School of the Technical University of Catalonia (UPC) has five bachelor degrees (4 year-long): Communication Systems Engineering, Audiovisual Systems Engineering, Electronics Engineering, Networks, and Telecom Science and Technology. Whilst the first two project subjects include topics which are common to all degrees and are performed by all the 4-student teams in the same class group, the Advanced Engineering Project subject (AEP) is specific for each degree, is performed by larger teams (9-12 students), and each project is unique.

According to the CDIO Standards, we designed the curricula structure using a mixed approach to integrate CDIO skills into the curricula: On the one hand, the skills pathways were defined by involving all courses. Every course may contribute to the learning of several skills at a given level (basic, medium, advanced) and should actively contribute to develop and assess two of them. On the other hand, four specific project-centered courses have been scattered along the curricula, at the second semester of each academic year. They all include design-build activities and put emphasis on the CDIO Syllabus fourth group of skills. Table 1 shows their main characteristics.

The product or system to be designed and built in AEP should be complex enough to need its breakdown in 3-4 subsystems. Then, 3-4 subteams of 2-3 students should design, build and test their specific subsystem and integrate it with the others in order to complete the full system. This approach pushes the coordination at sub-team level and also at full-system level and promotes several CDIO skills included in the syllabus points 3.1 and 4.

Table 1
Project subjects along the curriculum

Subject	Semester	Credits (hours)	Main topics and characteristics	Group size
Introduction to Engineering	2	6 (150)	System view Basic economics Project management Seminars Partially guided project (2.4 ECTS)	3-4
Basic Engineering Project	4	6 (150)	Regulatory aspects of ICT (2 ECTS) Open basic engineering project (4 ECTS) Focus on design and implementation of a given block of a complex system	4
Advanced Engineering Project	6	12 (300)	Seminars (< 20%) Whole design and implementation of an advanced and complex engineering project Different topic per group Focus on conception, innovation and entrepreneurship	9-12
Thesis project	8	24 (600)	Individual (by Spanish law) Performed in a company or research group, on campus or in an international exchange.	1

SUBJECT DESIGN

The course has 12 ECTS credits + 1.5 advanced math credits. These math credits are provided to ensure a high complexity level in the solutions and include seminars adapted to each project (optimisation, numerical calculus, advanced statistics…) and mentoring. The 12 credits mean 300 h of workload per person along the semester (15 weeks). The main part of this time is autonomous work, but the students also attend to seminars (2 hours per week) and have supervised attendance to the lab 6 hours per week. There are several short seminars (1-2 hours):

- system thinking
- creative thinking
- engineering design
- team work optimisation
- Belbin method
- business database search
- patents database search
- IPR

and longer seminars (several sessions) on advanced project management and on how to prepare a business plan.

The teams make the product specifications from the client requirements and complete the preliminary design tasks while studying specific topics about the project. The teams should undergo weekly meetings and three review meetings with the evaluators (preliminary design review PDR, critical design review CDR and final design review FDR). The documentation forms have been adapted from the LIPS model [3].

Table 2. Tollgates and delivarables

#	week	Tollgate	Deliverables
1	3	Preliminary Design Review	-Requirements and specifications - Project Plan
2	7	Critical Design Review	- Reviewed Project Plan - Project Report
	13	Preliminary FDR	
3	14	Final Design Review	- Reviewed Project Plan - Project Report
	15	Project presentation + Demo	- Poster - Final Report
	weekly		- Meeting minutes - Lab logbook

This first year of implementation, only students from Audiovisual Systems Engineering and Electronics Engineering are enrolled in the AEP course, given that these two degrees started one year before the others, as a pilot plan, and thus constitute the wavefront of our curricula implementation. The next year, students from all degrees will reach this point.

Assessment

The 60% of the course mark corresponds to the group performance evaluation:

- Preliminary Design Review………. 15%
- Critical Design Review……………. 15%
- Final Design Review………………. 30%

In the second year project implementation [2] we found that often the students had a different interpretation of the system performance specifications test criteria than the evaluators. To avoid any misunderstanding in that sense, a preliminary test of the whole system integration is performed one week before the FDR. The remaining 40% of the students subject mark is an individual performance assessment obtained from the observation of the students' performance in the laboratory and in the weekly progress meetings (20%) and from the group members cross-evaluation (20%).

SUBJECT IMPLEMENTATION

The implementation of AEP in each degree has been slightly different; we assigned two faculties to each project and we are still trying different strategies with the first cohort of students. Although the initial design of the subject specified unique projects, due to a change in the degree regulations we had 18 students in the Audiovisual Systems Engineering project, while the group size was specified to be 9-12. Thus we split them in two groups of 9 students which developed the same project and competed among them. The Electronics System project group had 9 students. This reduced global amount of students is due to the fact that we started three years ago with a pilot plan with only 2 of 5 degrees. Next year we await 80 students 6-9 projects in AEP and in two years, around 120 students (10-13 projects). Two faculties cover one or two simultaneous projects. The workload for each faculty is 6 hour/week in the initial phase and will be 4 hours/week (2 hours overlapped with the two lecturers) in the steady state.

Electronics Engineering project

As an example of an AEP project topic, the Electronic Engineering students are developing this year a pico-satellite. The pico-satellite is based on the CubeSat standard developed by Profs. Jordi Puig-Suari and Bob Twiggs at CalPoly and Standford in 1999. The basic CubeSat standard is a 10x10x10 cm^3 cube, with a mass of up to 1.33 kg, which are launched as piggy-back singles or in groups of three units [4]. Figure 2 shows a CubeSat previously developed by master students in our school and our ground station. CubeSats include all the subsystems encountered in real satellite missions:

- the on-board computer (OBC),
- the electrical power supply (EPS) and solar panels,
- the telecommunications system (including the radio transmitter, the antennas, the communication protocols…),
- the attitude determination and control system (either passive or active, including reaction wheels and the most advanced ones GPS receivers, or even thrusters and star-trackers), and
- the payloads, which are typically simple remote sensors (optical cameras, radiation detectors, miniature microwave radiometers, radio receivers…) or technological demonstrators.

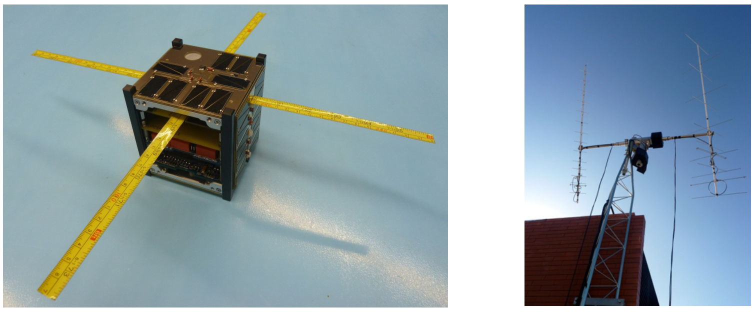

Figure 2. CubeSat developed at Telecom BCN and the ground station (EC3RCU)

We believe that CubeSats are an excellent teaching platform that includes many areas of electronics, telecommunications, RF, computer science etc. But it also introduces the 3rd grade students to the issue of reliability and testing, since their designs must survive thermal cycling, high vacuum, solar illumination conditions at Top of the Atmosphere (ToA), and vibrations as experienced during launch. Finally, it is a perfect excuse to force them to work and think globally, since their CubeSats, once in orbit, will have to communicate with any Ground Station of the GENSO [2] network.

Despite the students reaching the Advanced Engineering Project/Electronic Systems are in their 6th semester, out of a total of 8 in the degree, some of the required concepts have not yet been explained or are being explained in parallel courses. Others, such as testing, qualification, and reliability are barely mentioned in their studies, and hence this project becomes an excellent way to expose the students to these topics. To fill the gaps, while at the same time, provide a general overview of many concepts studied in their degree, during the first two weeks (total 12 h) out of a total of 13 to 15 weeks (depending on the semester calendar) an overview of the issues involved in the conception, design, implementation and operation of real spacecrafts, and in particular CubeSats is provided. The students are immersed in a 334 slides short tutorial of spacecraft systems engineering covering the following topics:

1. Introduction,
2. Orbits,
3. The Spacecraft Environment,
4. Thermal control,
5. Attitude control,
6. Solar Panels and Electrical Power System,
7. Telemetry, Tracking and Command Systems,
8. On Board Data Handling,
9. Product Assurance,
10. Spacecraft Electromagnetic Compatibility, and
11. A software tool to manage projects, including dynamic Gantt diagrams, detection of critical paths, repository of documentation etc.

From the above list, it is evident now that a large spectrum of the required expertise fall well within the fields of Electronics and Telecommunications Enginneering, which makes the students feel that what they have studied has a real application. In the first semester this course has been proposed, the total number of registered students is 9, and they have been organized in 4 teams of 2 people, led by a project manager, in charge of the their coordination. Each team has assigned a key subsystem of the CubeSat, so that they realize that their work is not only important, but of crucial importance for the success of the mission. In this first semester, the teams work deals with:

1. the electrical power supply system, including the solar panels, charger, maximum peak power tracking system etc.,
2. the telecommunications systems, including power amplifier, beacon, antenna, communications protocols …,
3. the attitude control system, either with a momentum wheel actuator and control or with magnetorquers, solar sensors, permanent magnet, mu-metals…, and
4. the payloads and technological demonstrators: Thermo-electrical power generation, visible camera and LCD shutter, Geiger counter…

The course is organized as follows:

- A weekly team meeting of 2 h on Tuesdays (12-14 h) where the students report their weekly progress to their colleagues and to the project manager, who leads the meeting. One of the students, acting as secretary, takes the minutes of the meeting, and notes the action items to be tackled during the following week. In these meetings, the role of the faculty is to stay in a secondary layer, to help the discussion to take off if it does not, which only happened during the first week, and to guide the technical discussions after they have presented and discussed the pros- and cons- of the different technical options.
- A tutorized lab work session of 4 h on Thursdays (8-12 h), where the two faculty and 2-3 teacher assistants address continuously the work performed by the different teams, asking them to use a critical reasoning to take the right design decisions at each step, to infer data when it is not readily available, or to obtain it from experimentation…
- On week 3, just 5 days after having finished the introductory seminars, the students are asked to deliver (as an ensemble) their first mission analysis using the professional AGI/Satellite Tool Kit software.
- On the weekly meeting of week 4, the students' design undergoes a Preliminary Design Review meeting (PDR) in front of the faculty, the teacher assistants, and their colleagues, who also have the right to ask questions.

- On the weekly meeting of week 8, the student's final design undergoes Critical Design Review meeting (CDR). The designs presented at the CDR meeting have already been tested in proto-board, but it is not after this meeting that the final design, manufacturing, and testing of the printed circuit boards (PCB) will be triggered. These PCBs will also be integrated in the last weeks of the course.
- Finally, on week 15, a final review meeting (FDR) of the whole system takes place, and a final exposition and presentation to students of other courses and degrees takes place.

As mentioned in the previous section, the students' evaluation has an individual part based on their presentations in the weekly meetings, their individual and team work as perceived during the tutorized lab sessions, and the reports and technical notes delivered.

Audiovisual Systems Engineering project

The goal for the Audiovisual Systems Engineering degree students' project was to design, build and test a system to map the acoustic response of a room. There are plenty of commercial simulators that provide such a graphical map but the experimental validation is performed by measuring in discrete points of the room with a sonometer. The goal in this project was to build a system which included a given number of auxiliary loudspeakers placed at the room corners, a microphone, a soundcard or recording system and a software application. The operator sweeps the room following an arbitrary path with the microphone and the system acquires both sound signals coming from the auxiliary loudspeakers that should allow positioning the microphone (a kind of acoustic GPS) and test sounds coming from one of the loudspeakers or the room sound system that should allow characterizing the room acoustic response. Figure 3 shows the system main idea.

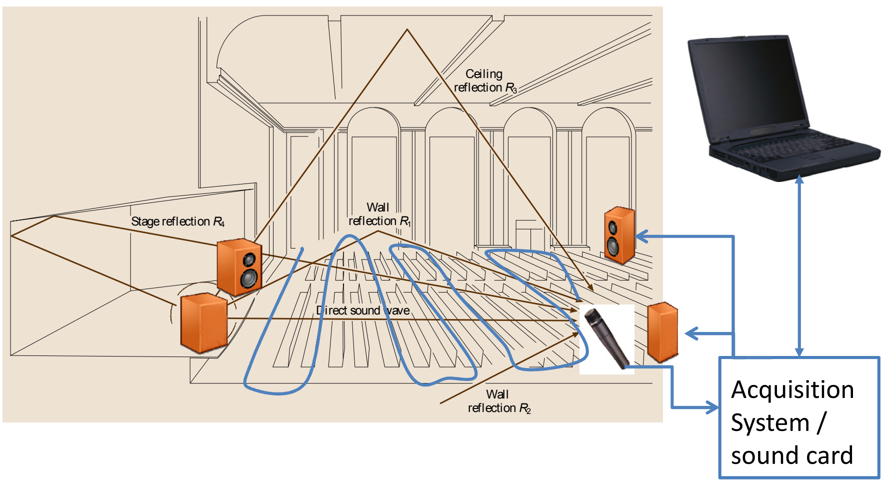

Figure 3. Automatic system to map the acoustic response of a room. The background image has been taken from [6]

The students enrolled in the Audiovisual Systems Engineering degree had an initial disciplinar knowledge (acoustics, signal processing) closer to the project's topic than the Electronics Engineering students. Then, they didn't need the preliminary seminars and started to plan and design just after the project client requirements were specified.

Set apart the initial seminars, the course operation has been similar to that described in the previous section. The two faculties switched their roles (client, supervisor, consultant) when needed. The students had a restricted access to the main resource, the room (figure 4), which was available 6 hours per week shared between both groups as a way to force a strict task planning. This also had driven the negotiation between teams and with the supervisors. In this project, one hour group meeting was performed for each group one time per week, with the presence of both lecturers acting as clients/supervisors and observing the individual performance of the team members.

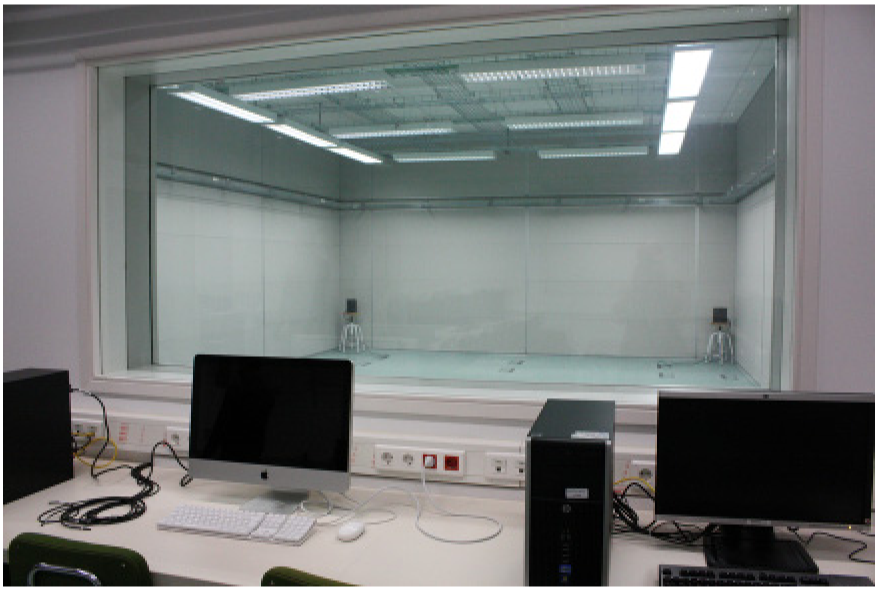

Figure 4. Room set-up for the Audiovisual Systems Engineering project

CONCLUSIONS

The Advanced Engineering Project closes the set of three design-build projects that the Telecom-BCN students perform in the first three years of their degree. In the fourth year, they will carry out a final project, most of them in another institution within the international exchange program.

The Cubesat topic chosen for the Electronic Engineering students' project has been a challenging and encouraging issue. The students are aware of working in a singular project. In fact, several Audiovisual Systems Engineering students asked to change their degree to have the opportunity of working in the satellite project.

The concurrence of two teams performing the same project in the case of Audiovisual Systems Engineering, although not initially preferred, has shown positive effects due to the fair competence between the two teams and the need to manage how to share the resources (room, loudspeakers, acquisition system).

The team of faculties that have designed and implemented the AEP for first time are the same that developed the previous two project subjects and have had the opportunity of following the evolution of the first cohort of students. It is really satisfactory and encouraging to observe the growth in maturity and responsibility of the students and the performance they show in most of the curriculum skills. It is true that this first cohort is under the Pigmalion effect and performs clearly better than the following cohorts, which are now in the second year. Nevertheless, the experience allows us to test the course design with a favourable set of students and foresee the measures needed to correct malfunctions in more general cases.

Joining the three year project courses, 21 faculties are now involved in the project subjects' path. All of them have been mentored by the initial set of 5 lecturers and 6 of them will teach AEP the next year.

REFERENCES

[1] Bragós R. Alarcón E. Camps A. Pegueroles J. Sardà J. and Sayrol E., Conceiving and designing an "Introduction to Engineering" course within the new curricula at Telecom BCN, UPC Barcelona. Proceedings of the 6th International CDIO Conference, École Polytechnique, Montréal, 2010.

[2] Bragós R. Alarcón E. Pegueroles J Camps A. Oliveras A. García-Hernández M. and Sayrol E. Design of the Basic Engineering Project subject for the second year of Electrical Engineering at Telecom BCN. Proceedings of the 7th International CDIO Conference, Technical University of Denmark, Copenhagen, June 20 - 23, 2011

[3] Svensson T. and Krysander C., "The LIPS project model. Ver 1.0 " Linköping University,Sweden, 2004.

[4] Cubesat web site: http://www.cubesat.org/, last visited January 10th, 2012.

[5] GENSO web site: http://www.genso.org/, last visited January 10th, 2012.

[6] Rossing, Thomas D. (Ed.) Springer Handbook of Acoustics. Springer 2007.

Biographical Information

Ramon Bragós is associate professor at the Electronics Engineering Department of Technical University of Catalonia (UPC). His current research focuses on electrical impedance spectroscopy applications in biomedical engineering. He lectures at Telecom BCN, where he is the Associate Dean of Academic Innovation.

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Eduard Alarcón is associate professor at the Electronics Engineering Department of UPC. His current research includes signal and energy processing on silicon. He lectures at Telecom BCN, where he is the USA-Liaison Adjunct to the Dean.

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