CONCEIVING AND DESIGNING AN "INTRODUCTION TO ENGINEERING" COURSE WITHIN THE NEW CURRICULA AT TELECOM BCN, UPC BARCELONA

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ABSTRACT

This paper describes a course devoted to "Introduction to ICT Engineering" which, building upon initial restrictions and specifications, has been conceived, designed and implemented at Telecom BCN, UPC BarcelonaTech. This is the first of a set of four design-build courses distributed along the new degrees curricula structure, which have been designed using the CDIO Syllabus and Standards as Engineering Education paradigm. The course is organized in three intertwingled tracks, covering (a) the systems view of complex ICT systems; (b) the basic economics and management concepts of ICT products and services, including project management, and (c) the lab practice of these methods, together with the acquisition of generic skills by the realization of a design-build project (focused upon an undewater robot with emphasis in electronic communication aspects) in student teams. The design and implementation of the lab system ICT-related subsystems displays problems whose advanced solutions will be discovered in the subsequent courses within the curricula. The course is currently running as a pilot course with two small groups (30+30 students) before fully deploying it next year to all the new degrees.

KEYWORDS

Introduction to Engineering, Design-build experiences, 1st year course, curriculum design

INTRODUCTION

At Telecom BCN, the Electrical and Telecom Engineering School of the Technical University of Catalonia (UPC), we started three years ago the design of the new curricula within the European Higher Education Area framework (Bologna process). Five new bachelor degrees (4 year-long) have been designed. Two of them (Audiovisual Systems Engineering and Electronics Engineering) have already started their courses this academic year (2009-2010). The remaining three degrees (Communication Systems Engineering, Networks, and Telecom Science and Technology) will start in September 2010.

The adaptation to the Bologna process allowed us to perform an in-depth reorganization, so that CDIO was chosen as paradigm for new curricula design. The learning outcomes were identified; the skills and abilities list was defined and developed by matching our University standards with the CDIO Syllabus[1]. Finally, the curricula structure was established. We used a mixed approximation 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.

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 Guided project	4
Basic Engineering Project	4	6 (150)	Seminars (< 20%) Open basic engineering project Focus on design and implementation.	6
Advanced Engineering Project	6	12 (300)	Seminars (< 20%) 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

We are currently in the first year of the implementation of two new engineering degrees (40 + 40 students) and the following academic year, the remaining and more massive three degrees (up to 260 students) will start. The entry year is selective, thus the students should pass a given number of subjects from the first semester to be allowed to attend the second semester and should pass all subjects form the first year to be allowed to attend the second year. According to

this, near 30 students per degree (27+29) have been allowed to attend the “Introduction to engineering” course in the second semester of the first year. The two class groups constitute the first cohort that acts as pilot experience in the implantation of the new methodology, given that the first two years are common to all degrees.

In the first semester they have completed algebra, calculus, physics, and introductory courses to electronics and computers. In the second semester they are studying advanced calculus, electromagnetism, circuits theory, object-oriented programming and introduction to engineering. This last subject was placed at the second half due to regulations (coherence in the first year structure between engineering degrees of the same area). This fact is considered positive because the students which attend this subject have already demonstrated a given performance and have also acquired a set of knowledge and skills that allow coping with basic design-build projects.

THE “INTRODUCTION TO ENGINEERING” SUBJECT

Initial Specifications and Restrictions

This course is formally called “Introduction to ICT Engineering” (ICT stands for “Information and Communication Technologies”) and its design has taken into account several initial specifications and restrictions:

- As stated in the 4th CDIO standard [1], it should provide the framework for engineering practice in product and system building, and introduce essential personal and interpersonal skills.
- Being at the first year, and due to our University regulations, it should include basic economics topics.
- According to the recommendation of our strategic plan committee and steering committee, it should introduce the system view in complex ICT engineering products, processes and services. This aspect agrees with CDIO Syllabus point 2.3.
- Also according to regulations (homogeneous structure of first year courses), the subject should have 6 ECTS credits (ECTS, European Credit Transfer System), which corresponds to a student workload of 150 hours along 15 weeks. 66 of these hours are carried out in a classroom or laboratory with lecturer support, whilst the remaining 84 hours correspond to autonomous work, both individual and group work. The students have 3 regular sessions per week, two of them of 2 hours and one of 1 hour, plus the autonomous work.

Course Learning Outcomes

The main course goal is: “To understand the engineering context and acquire motivation through the exposure to complex system building”. As a secondary goal, the course should help to integrate the basic knowledge the students have already learnt and, specially, trigger the curiosity for the concepts they will learn in the subsequent disciplinary courses.

As main learning outcomes, after attending this course, the students should be able of:

- Have a systemic view of ICT products and services
- Describe the main concepts and perform basic calculations about the economics of design, production and commercialisation of ICT products and services
- Carry out the basic steps on project planning, development and documentation

They should also have acquired the learning outcomes of several generic skills. Our University has defined a set of seven mandatory skills and our School has added three extra skills and defined the outcomes of all of them according to CDIO Syllabus and with three depth levels (basic, medium, advanced). They are displayed in table 2. This course, as all other project courses, helps to improve the vast majority of the transversal or generic skills, but in the organization of the skill pathways, the Introduction to Engineering course has the explicit request to provide and assess four of them at 1st (basic) level. Those which are more difficult to assess in conventional courses have been chosen.

Table 2
Generic skills stressed and assessed in this course

#	Generic Skill	Exposed	Stressed	Assessed
1	Innovation and entrepreneurship	X	X	X
2	Societal and environmental context	X	X	X
3	Communication in a foreign language (English)	X	X	
4	Oral and written communication	X	X	X
5	Teamwork	X	X	
6	Survey of information resources	X	X	
7	Autonomous learning	X		
8	Ability to identify, formulate and solve engineering problems	X		
9	Ability to Conceive, Design, Implement and Operate complex systems in the ICT context	X	X	X
10	Experimental behaviour and ability to manage instruments	X		

Course Design

In order to achieve these requirements, we organized the subject in three parallel tracks, connected between them through a common topic. This is coherent with the three regular sessions per week they have. The three tracks cover the three main learning outcomes: 1-System View, 2-Basic Economics, 3-Project management and development through a hands-on project.

Track 1: System View

Regular sessions of 1 hour/week.

Goals/learning outcomes. The students should be able to:
- Describe the system structure and main characteristics and identify the involved technologies of several complex ICT products and services presented by the faculties and other students.
- Identify the features and business models which are common to the different ICT systems.
- Find information about an ICT product or service, other than those used as examples. Summarize it, clearly identifying the following aspects: Need of the product, business model, system structure, involved technologies, societal and environmental implications.
- Plan and perform a 15 minutes oral presentation devoted to the product or service assigned and answer correctly the questions raised from the audience.

Track 1 structure: 5-6 sessions in which the lecturer exposes the students to face the system structure and main technological and economical aspects of several complex ICT products (Internet, cell phone, GPS, …). All presentations include the following aspects: Background, need of the product, system structure, involved technologies, abridged history, business model and societal implications. The presentations are also used to introduce concepts that link with other disciplinary subjects. Subsequently, a seminar on oral and written communication follows, and then, several additional sessions in which the students perform cooperative work preparing and presenting additional ICT products or services. The student's presentations are 15 min long and are performed by two people (out of a 4 person team). A session allocates 3 presentations.

Track 2: Basic Economics of design, production and commercialisation of ICT products and services

Regular sessions of 2 hours/week.

Goals/learning outcomes. The students should be able to describe the main concepts and perform basic calculations on the economics of production and commercialisation of ICT products and services. Roughly, the goal of this track is to impress in the mind of the students that the design and production of every product has a cost and requires an initial investment that expects a return. In the third year, they have a more formal Economics and Management 6 ECTS subject and they also have seminars spread in the project courses.

Track 2 structure: Regular sessions in which a specific lecturer from the Management and Business Department gives a lecture or set of lectures about each of the following topics:
- Introduction to project management
- Idea generation tools: SWOT and Brainstorming
- ICT Business models
- Cost determination
- Profitability of investments
- Marketing

The main deliverable of this track is a business idea that should be developed by teams at a very basic level and presented in public. The business idea should be closely related with the common topic chosen in the course and which is also used in track 3 (hands-on project). Presentations take place in the last week of the course and should include the following items: To identify a need, to propose a business idea that covers this need and to evaluate costs, investment and benefit (at a very basic level). The final presentation is performed by the two remaining team members who did not present in track 1.

Track 3: Design-Implement experience

Regular sessions of 2 hours/week.

Goals/learning outcomes. The students should be able to:
- Perform the basic steps on project planning, development and documentation, following a partially guided design, and complementing it with small and open design-implementation activities.
- Acquire the learning outcomes corresponding to the basic level of the generic skills specified in Table 2.

Track 3 structure: This track is performed from the first day in a laboratory in teams of 4 students. Although the engineering degrees in our School are ICT related, we consider that the topic around which the project and the track 2 business idea is to be built, should have moving parts to boost the first-year students motivation. Then, the project will be typically built around a robot or a vehicle. The implementation of the mechanical parts following a guided design can take 3-4 weeks. It would not need other machining skills than those that the students had acquired in the Technology subjects of High School. This activity would promote the team consolidation and the distribution of tasks. Given that the concepts about project management are lectured in parallel in the track 2, the first 3 weeks of the project are performed in an intuitive basis with very little guidance. After that, the students are asked to think about which tasks had been performed, which team members were devoted to each task and which tasks had been or could have been performed in parallel. After that, they document in a task list and in a Gantt diagram the already carried out part and are asked to plan the remaining part of the project. This second part is a small but complex ICT system, complex in the sense that it includes several heterogeneous subsystems. Typically it would be the integration of one or several sensors, conditioning circuits, an acquisition system, a communication link and a program that reads and performs a basic processing of the acquired data. They should take decisions on how to configure and connect the systems and design a few small parts (conditioning circuits or data processing code). Of course, they start from a set of client requirements from which they should write a product specification, a project plan, progress reports and a final report. The documentation procedure is a simplified version of the LIPS method [2].

Additionally, several out-of-track 1 or 2 hour seminars are spread in the course, with the following topics: sustainability and social commitment, information gathering, and intellectual and industrial property. The last two topics are presented by staff of the University Library.

Course Implementation

Common Topic for tracks 2 and 3

The chosen common topic for the following 5 years is the remotely operated underwater vehicle (ROV) and its applications. Being the Track 3 a partially guided project, the economic aspects are very simple and do not allow to exploit the concepts explained in track 2. To overcome this problem, the students should prepare a business idea based on a product or service (pollution measurement, archaeological search, cleaning, security, …) built around a ROV and present it in public. This common topic acts as a liaison between tracks. We call this project ICT-iNeo, which is a play on words related with “ictineo”, a submersible designed and built in Barcelona by Narcis Monturiol in 1859 [3]

A good alternative for the mechanical part of the project, in the Track 3, is the SeaPerch platform [4], a simple remotely operated underwater vehicle (ROV) conceived and developed at the MIT Sea Grant College Program. This part of the underwater robot can be built using PVC pipes in the first 3-4 sessions, favoring the consolidation of the work teams. Afterwards the students face the challenge of designing and building a specific ROV payload that changes every year. The foreseen projects include measurement and data logging of water parameters (temperature, depth, light absorbance, conductivity, …), communication (Wired, RF, optical, acoustical), control (efficient motor driving, computer control of navigation) and networks. This first introducing year we have requested our students to design and build a system able to acquire water temperature and depth (through pressure) pairs along the trajectory of the underwater vehicle, with a distance limit of 10 m and a depth limit of 3 m. The system should store the

measured data and also transmit them using an additional wire pair in the tether that is used to control the 3 vehicle motors.

The students have acquired the basic knowledge in electronics to understand the pressure and temperature sensors behavior. At the “Circuits Theory” subject, which is lectured in parallel to our subject, they work with basic Operational Amplifiers based circuits that allow them to perform a partially guided design of the amplifiers. They connect the output of both circuits to a small datalogger (Logomatic v2) from SparkFun [5]. The datalogger acquisition routine is already programmed. They can configure the system to choose the measured entries and the acquisition rate. Additionally to the data storage in a micro-SD card, already present in the datalogger, we have modified the program to send the acquired data in a basic serial format. This allows the students to send the data through a wired link and discover the need of a physical (bit rate and levels) and logical (format, headers, …) protocol. They can easily manipulate the parameters of this protocol through program parameters. Lots of concepts which will be formally studied in subsequent subjects are introduced here: sensitivity, gain, dynamic range, coupling of dynamic ranges in acquisition chains, A/D conversion, errors, calibration, data transmission, protocols, …). The working hypothesis is that the students should pay more attention to the formal explanations of mathematical models and technological solutions of these concepts after having realized their need in a real system they have built.

At the moment of closing this paper, the students have already set-up the measurement and acquisition of two variables (P and T) and are working in two fronts: building the final version of the circuit in a prototype board together with the datalogger, and understanding the communications protocol. In 3 more weeks they should be able to perform a contest in a swimming pool to demonstrate and compare the performance of their systems.

Track 1: System View

The topics chosen to illustrate the system view of complex ICT systems in the first 6 sessions of this year are the following (a sounding sentence announces each topic):

- Cochlear implant: “Hear this! The tinniest ever bionic implant”
- Cell Phone: “Ubiquitous communications crystallize: Silicon chips for cellular phones”
- Undersea communications: “The big battle against the sea"
- The Voyager: "The Farthest Communication Ever Made"
- Internet: “The way Alexander the Great got connected”
- Earth Observation Satellites: “Taking the Pulse to the Planet”

In each session, additionally to the mentioned aspects presented for each topic, a few concepts are introduced. For instance, in the “Cochlear Implant” topic, the concepts of decibel and the frequency decomposition of a signal; in the presentation about the Voyager, the decrease of electromagnetic (EM) field with distance and the signal to noise ratio.

Two days before each presentation, a web page or document related with the topic is made available in the moodle-based LMS system of the University (Atenea digital campus). This information is complementary but not substitutive of the presentation. For instance, for the “Cochlear Implant” topic, they should read a web page about the physiology of the ear and for the “Cell Phone” topic, an abridged report from the European Commission about the effects of EM fields on human beings. To ensure that the students read these materials and attend the presentation, a previous and a post questionnaire are placed in the digital campus. They should answer them in 20 min and they have two attempts. The result is a very small part of the assessment, which is mainly given by their own presentations, but if they do not perform the

questionnaires, the mark of this track is reduced. During the presentations, we have used the TurningPoint voting system to dynamize the sessions.

At the end of the 6 sessions performed by the lecturers, they choose a topic for its own presentation from a list proposed by the faculties. Then, three weeks are devoted to present seminars about oral and written communication and about intellectual and industrial property. This gap gives time to the students to prepare their 15 minutes presentations which they will perform the last three weeks at a rate of three groups per session.

The synchronization of the three tracks can be seen in the table 3. From the originally available 15 weeks, due to the holiday days and the fact that this subject does not have final exam, 13 sessions are available for each track.

Table 3
Course calendar

<table>
<tr><th>Week</th><th colspan="2">Track 2
2 h/week
Management and Business</th><th>Track 1
1h/week
ICT System View</th><th>Track 3
2/h week (split group)
ICT-iNeo Project</th></tr>
<tr><td>1</td><td>Course introduction</td><td>Information gathering</td><td>“Cochlear Implant”</td><td rowspan="13">ICT-iNeo project</td></tr>
<tr><td>2</td><td colspan="2">Introduction to project management</td><td>“Cell phone”</td></tr>
<tr><td>3</td><td colspan="2">SWOT and Brainstorming</td><td>“Undersea phone communication”</td></tr>
<tr><td>4</td><td colspan="2" rowspan="2">Project management</td><td>“The Voyager”</td></tr>
<tr><td>5</td><td>“Internet”</td></tr>
<tr><td>6</td><td colspan="2" rowspan="2">ICT Business models</td><td>“Earth observation satellites”</td></tr>
<tr><td>7</td><td rowspan="2">Seminar on oral and written communication</td></tr>
<tr><td>8</td><td colspan="2">Cost determination</td></tr>
<tr><td>9</td><td colspan="2">Profitability of investments</td><td>Seminar on intellectual and industrial property</td></tr>
<tr><td>10</td><td colspan="2">Marketing</td><td rowspan="3">Students presentations on system view</td></tr>
<tr><td>11</td><td colspan="2" rowspan="2">Sustainability and social commitment</td></tr>
<tr><td>12</td></tr>
<tr><td>13</td><td colspan="4">Presentations on business ideas</td></tr>
</table>

Resources

As mentioned in the introduction, this first year implementation is being performed with a reduced set of students, two groups of around 30 people, in a pilot experience. The track 2 (economics) is being carried out by a set of 4 lecturers from the Economics and Management Department. Each one lectures the lessons corresponding to their specialty (project

management, costs, marketing, ...). The book “Product Design and Development”, from Karl Ulrich and Steven Eppinger [6] is used to prepare this part.

Four more faculties teach the tracks 1 and 3, two of them in each class group, and both are simultaneously in the classroom. This structure has been built in order to train a team of people that could assume the second implementation phase of the subject with the 250 expected students the next year. Each actual lecturer will form a pair with a new one next year in one or two class groups. Every lecturer who plans to teach in the higher project courses (2nd and 3d year) should also be or have been involved in the “Introduction to Engineering” course, in order to keep the coherence in the methodology. With this structure, we plan to have a set of around 40 lecturers teaching in the project subjects in 4 years.

Six granted teaching assistants help us with the preparation and testing of the project alternatives (2 of them) and supporting the students in the laboratory (2 TAs in each class group).

The electronics engineering laboratories already have a modular structure that allows the work in teams. We have added a small mechanical workshop that complements them and allows making the mechanical parts of the projects. The current Campus improvement program includes building new spaces for teamwork and a larger mechanical workshop, as well as spaces to store the student’s projects. We have got specific funds from the University to buy the materials and tools necessary to carry out the projects. Most of these materials are reusable.

CONCLUSIONS

From initial restrictions and specifications, an “Introduction to Engineering” course has been conceived, designed and implemented at Telecom BCN, UPC, Barcelona. This is one of four design-build subjects that the students will perform according to the new degrees curricula, which have been designed using the CDIO Syllabus and Standards as Engineering Education paradigm.

The course is organized in three tracks, covering the system view of complex ICT systems with presentations performed both by the faculties and the students; the basic economics and management concepts of ICT products and services, together with project management concepts, and the practice of these methods, together with the acquisition of generic skills by the realization of a design-build project in teams of 4 students.

This project allows starting with a simple mechanical device which is appealing and even fun. The student’s performance does not depend upon their previous knowledge but upon their ability to follow a plan. The design of the system ICT-related subsystems displays problems whose advanced solutions will be discovered in the following courses of the curriculum. The whole project allows putting in practice the project management concepts presented in track 2 and which will be reinforced in the following 3 project subjects, whose complexity and degrees of freedom grow year by year.

The course is being carried out (operated) with two small groups (30+30 students) in a pilot experience before applying it to all the new degrees next year. At the time of closing this paper, there are still 4 weeks to finish this term. Next June we will be able to complement the description by presenting the final results of the course first-round implementation and operation during this semester.

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Biographical Information

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