PERFORMANCE ASSESSMENT OF A CDIO-CENTRIC INTRODUCTION TO ENGINEERING COURSE

Josep Pegueroles
Telecom BCN, Telematics department, UPC, Barcelona, Spain

Ferran Silva
Telecom BCN, Electronics Engineering department, UPC, Barcelona, Spain

Esteve Pallarés
Telecom BCN, Telematics department, UPC, Barcelona, Spain

Sergi Bermejo
Telecom BCN, Electronics Engineering department, UPC, Barcelona, Spain

Antoni Broquetas
Telecom BCN, Signal Theory and Communications department, UPC, Barcelona, Spain

Ma Jose Soneira
Telecom BCN, Signal Theory and Communications department, UPC, Barcelona, Spain

ABSTRACT

“Introduction to ICT Engineering” is the first of four project-oriented courses distributed along all the degrees in TelecomBCN, at the Technical University of Catalonia (UPC). This course was given for the first time during the spring semester of 2010, and currently we are reaching the end of the sixth edition. Following the 4th CDIO standard, it provides the framework for engineering practice in product and system building, and introduces essential personal and interpersonal skills. Among its main goals we can cite “to make students understand the engineering context and acquire motivation through the exposure to complex ICT system building”. The course conception and design was already detailed in a communication in the 6th international CDIO conference. It was first implemented, according to the original design, in Feb 2010 with a reduced number of students; but after this initial experience and six editions, the course achieved its regular operation by including many modifications, mainly motivated by the feedback we got from faculty and students. This paper describes how the initial design has been dynamically adapted to the specificities of a 300 students-per-year course, especially regarding contents, methodology and assessment. The evolution of pass rate and student satisfaction is also detailed.

KEYWORDS

Case Studies in CDIO Implementation, Introduction to Engineering, Design Review, Generic Skills, Pass rate, Students' Evaluations of Educational Quality.

1. INTRODUCTION

The course named “Introduction to ICT Engineering” (ICT stands for Information and Communication Technologies), hereinafter "ENTIC", is the first step that the students of the Telecommunications School in Barcelona (ETSETB-TelecomBCN) take in their itinerary of courses based on projects.

In 2007 and during the remodeling of the degrees when adapted to European Higher Education Area (EHEA); ETSETB-TelecomBCN took the opportunity to include in its curricula the principles of the CDIO initiative [1]. Particularly, and according to the 4th CDIO standard [2], they included an Introduction to the Engineering course (ENTIC). The description of how it was conceived and designed was previously presented in [3] and it was first offered in Sept 2010. The more detailed description of the course for students is also available on-line at [4].

The main goal of the course is to make the student understand the engineering context and to provide them motivation to complex system building by means of a “technology in practice” approach. Besides to help the students to put in practice the specific background that is included in previous and concurrent courses and to stimulate their interest in topics they will learn in the subsequent disciplinary courses.

Roughly speaking, and based on the SeaPearch project [5], the students devote 13 weeks to build a remote underwater vehicle (RUV), capable of measuring water parameters and afterwards, sending them, using a communication device, to a computer where they can process and display the acquired data. We familiarly call the RUV ICT-iNEO due to the pioneering submarine launched in 1864 by the inventor from Barcelona Narcís Monturiol.

Around this appealing task, i) we show to the students that an ICT product/service is a complex system ii) we introduce them to the project management, and explain how this product/service can be commercially exploited and iii) we explain, in a very introductory fashion, the different fields they can find in their studies (electrical engineering, computer communications, signal processing). These three approaches correspond to the different tracks we have in the design of the course, and are better explained in the next section.

In this work, we sketch how the ‘Introduction to the Engineering Course” was finally implemented, the main problems we found when operated and the evolution it suffered along the 6 editions in which it has already been delivered. We also include some figures about the performance of the course, especially the pass rate, and how impacted the changes in the assessment method to this figure and to the students opinion about the course.

The rest of the paper is structured as follows. In section 2 we summarize the main goals and structure of the course, in the way it was designed in its first edition. Section 3 is devoted to the description and analysis of the main problems that were detected, by students and faculty, when this course was under operation, in its first editions; and describes the solutions and redesign proposals to overcome the detected problems. Section 4 shows figures about the evolution of the pass rate, and students' satisfaction. Finally, we conclude with section 5.

2. COURSE IMPLEMENTATION OVERVIEW

As previously stated, this is the first project-oriented course that the students can enroll to. It is located in the second semester of their curriculum, and it can be followed after passing 5 previous courses on physics, mathematics, electronics and computers. It provides the framework for engineering practice in product and system building, and introduces essential personal and interpersonal skills.

Structure

The course is organized in three intertwined tracks, following the three different approaches we give to the same project. (Figure 1):

- Track 1 aims to give the students the idea of ICT products and services as complex systems that are composed of different modules/subsystems that in turn include different technologies and expertise fields. This track is delivered in 13 hours (one per semester week) and also includes a seminar on informational skills and written and oral communication skills. At the end of the track, the students, in groups of 4, have to make a short presentation on a complex ICT system of their choice.
- Track 2 corresponds to the introduction to project management. The students are taught how a project is planned and documented, how the execution is assessed, and the group and resources are organized. Following the LIPS project model (Linköping Interactive Project Steering) [6] we ask the students to perform all the tasks related to the development of the Remote Underwater Vehicle (RUV) according to the LIPS rules. We also include in this track some basics on cost and budget calculation as well as SWOT analysis. This track is delivered in 26 hours (two per semester week). At the end of the track, the students, in groups of 4, have to present a Business Plan based on the RUV they develop in Track 3.
- Track 3 is the hands-on lab. In groups of 4 people, each one assuming an specific role (leader, documentation responsible, R&D, responsible of the material) and following the planning and project management method they studied at Track 2, have to build their own RUV with enhanced functionalities (measuring and transmitting data to a processing center). The system complexity viewed and studied at Track 1 is also tangible here. This track is delivered in 26 hours (two per semester week). At the end of the track, the students, in groups of 4, have to finish their own RUV and pass all the tests they specified in the requirements specification document.

Figure 1. Different approaches to the same project

Thus, this 3-track structure is assigned 6 ECTS, which represents an expected student workload of 150 hours (11,5 h/week), performed in a 5 in-class + 6,5 out-of-class hours per week.

Generic Skills

An important assignment of the school committee to the project-oriented courses track was that it had to lead the inclusion of generic skills into the new curricula. After the redesign of the degrees, generic skills had been spread to all the courses. However, because a certain number of faculty found difficult the practical application of generic skills, and especially their assessment, the project itinerary decided to include only the assessment of four of them (the regular courses are only asked to assess two generic skills) but also work the ten total generic skills that are included in the whole curricula, with special emphasis in seven of them. Table 1 shows the complete list of generic skills pointing out which of them are assessed.

Table 1. 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		

In this way, ENTIC also acts as a living lab of how the generic skills can be seamlessly included in regular courses and are supposed to be the inspiration and example to the rest of the faculty.

Assessment

It is worth to mention how this type of course is assessed. It will also be briefly discussed in next section, because it is one of the problems we found in its first implementation. The same as the ICT systems we teach, the course is complex and thus its assessment. We have plenty of evidences that we collect during the semester in order to provide to the student the appropriate feedback and the final qualification. This, on the other hand, probably results in a too heavy load to the faculty that is not willing to devote these efforts.

Red items in Figure 2 depict the minimum number of deliverables the students should carry out and upload the corresponding documents to the e-learning platform we use (Moodle-based).

Basically, in Track 1, for each example of complex system we show to them (VSC), they have to read a related document prior to the lecture and answer a previous questionnaire. Similarly, and after the exposition, we ask them to answer a post-questionnaire. Moreover, in the same track, groups have to choose the complex system they are going to work, look for proper references to base their presentation on, structure the index of their document, write a short paper about it, and present it using slides to the rest of the groups.

Deliverables in Track 2 consist in the planning of their lab work, according to the LIPS model we teach them, think on a business idea based on the RUV platform, make the SWOT analysis, cost determination, and write down their company mission and vision. Finally they summarize all this in the Business Model document and present it, using slides, to the rest of the groups.

The Track 3 requires maintaining the regular documentation in a laboratory: pre-lab and weekly report for each session. Moreover, we ask them the requirements specification document, together with intermediate evaluations (rubric) of the on-going work, as well as the Final Report.

The Project Plan and the Requirements Specification documents are supposed to be evolving and versions updated of them should be also presented during the course.

Track 2 and Track 3 correspond to the 40% of the final qualification, and Track 1 evidences weight 20%.

Week	Track 1 1h/week ICT System View	Track 2 2 h/week Management and Business	Track 3 2/h week (split group) ICT-iNeo Project
1	Introduction and Project Documentation	Project Planning	Mechanical 1 (*PreLab) (*Report)
2	VSC1 RUV(*PreQuest)(*PostQuest)	Project Documentation (*Project plan exercise)	Mechanical 2 (*PreLab) (*Report)
3	Informational skills Seminar	Business Models	Mechanical 3 (*PreLab) (*Report)
4	WP2 Explanation (*CS Choice + Search of proper reference)	Business Models 2	Rubric (*Eval) + Electr 1 (*PreLab) (*Report)
5	VSC2 (*PreQuest)(*PostQuest)	SWOT and Brainstorming	Electr 2 (*PreLab + Project Requirements + Proj Plan) (*Report)
6	EXAM	Marketing (*StrategicPlan)	Electr 3 (*PreLab) (*Report)
7	WP3 explanation	Cost Determination 1	Electr 4 (*PreLab) (*Report)
8	Seminar on oral and written communication 1	Cost Determination 2 (*CostDetermination)	Rubric (*Eval) + (*Com 1 + PreLab) (*Report)
9	Seminar on oral and written communication 2 (*index of presentation)	Profitability of investments 1	Com 2 (*PreLab + Project Requirements + ProjPlan) (*Report)
10	VSC3 (*PreQuest)(*PostQuest) (*CS extended abstract + *CS Presentation Slides)	Social commitment (*Company Mission and Vision)	Com 3 (*PreLab) (*Report)
11	Presentations 1	Sustainability (*BM slides)	Com 4 (*PreLab) (*Report)
12	Presentations 2	Presentations	Rubric (*Final Report)
13	EXAM	Presentations (*Business Plan Final Report)	Disassemble

Figure 2. Detail of each session of the course and collected evidences

3. REVISITING THE COURSE: MAIN DRAWBACKS AND PROPOSED CHANGES IN THE COURSE DESIGN

In the previous sections we summarized the main aspects of ENTIC in the way they were designed in its first edition. We should state that this was the first time that this type of course was offered as compulsory in our school (for more than 300 students per year). As newbies, we learnt a lot from that first experience. Next, we briefly explain the difficulties we found in some aspects and how we tried to overcome them. To follow a structured analysis, we follow the different aspects taken into account in “Teaching for Quality Learning at University” [7]

Content

One of our main concerns when designing the course was to have a hands-on lab related to the degree the students are enrolled to. In this sense, we decided to adapt the SeaPerch project to electrical engineering and computer science by introducing the acquisition, processing, transmission and display modules of data. We supposed that in case students did not have the required background they would investigate by their own. This turned to be unrealistic. At the end we had to change the lectures on complex systems to include specific content they need in the lab. We tried to keep a certain level of autonomous learning, but also more detailed description of the work we were asking had to be included to allow the majority of the students to follow the course.

Structure

Although we considered it pretty straight-forward, the 3-track approach to the project was the most difficult aspect to embrace for students. Students said they perceived the tracks as unconnected, mainly due to the fact that different faculty delivers different modules of the course, and they do not see how it all fits till the end.

In this sense we have i) reduced the number of lecturers, ii) introduced links between tracks (explanation of content of Track 3 in Tracks 1 and 2) iii) make an overall presentation of the course in the first class of each track, and explicitly point out how it all fits at the beginning of the course.

Percentage of autonomous work

This is probably the most sensitive item for professors. We assumed that students, when entering an engineering degree would be able to face technical problems by autonomous learning. This is not true. It is very difficult to conduct a successful experiment by only providing the problem definition. We, at the beginning, designed the course with few step-by-step (wizard like) supporting material. But, the experience demonstrated that it was very difficult to conduct a successful project by just providing the problem definition.

It was found that the students either did not achieve the minimum goals or decided to copy the homework. It was decided to decrease the demand for autonomous work by including more detailed information on the steps they had to follow in their daily work.

Work load

Students usually take this course together with 4 other subjects (math, physics, electronics, programming).They have a significant workload in all of them, and have the extra-pressure that have to pass all the courses to enroll to any course of their second year. Usually, students complain about the excessive workload they have to bear and the diversity of work to be carried out in the 3 tracks of the course. Actually, we do not believe it is more than the 6 ECTS work (150 hours) they are expected to devote. However, we rearranged the due date of the deliverables to avoid unwanted overlaps with deliverables from other courses.

Assessment

The students concerns about assessment are only related to the number of tasks and deliverables. We strongly believe that a project oriented course need a quite high number of evidences that allows us to give them feedback in a per week basis. We need to detect low-performance to try to correct it or recommend the student to drop the course before the 7th week. Students who regularly follow and deliver the tasks should not have problems in passing the course.

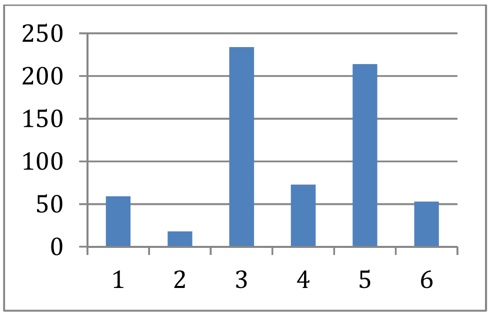
On the other hand, this is a very complicated and hard task to carry out by the faculty. In contrast with focused basic or technical engineering disciples, the course is very broad in scope addressing technical, experimental, organizational and management aspects. Finding an effective way to educate and assess first year students in all these aspects is a challenging and demanding task requiring a quite high amount of hours. We are trying to reduce the number of students per group, in order to keep the professor workload under control (a maximum of 12 students is very appropriate for a proper continuous assessment). However, and due to budget restrictions, it couldn't be possible in all the groups, and we do not know if in the future this will be worse. We have to think on an alternative plan, maybe reducing the number of evidences, grouping them, or even assuming that not all evidences need to be feed-backed to adjust this workload. For each student we observe a very strong correlation in the marks obtained in the different assessed aspects, this fact allows a substantial simplification of the assessment procedure

4. PERFORMANCE ASSESSMENT

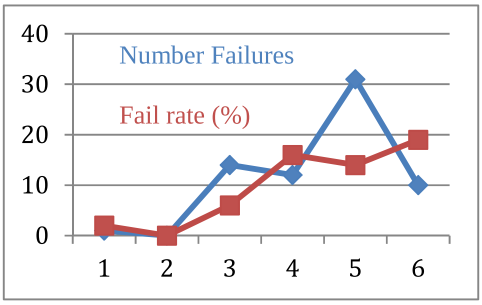
We mainly have two different data sources for the performance assessment of the Introduction to the engineering course. On one hand, the qualification lists from the different semesters, and on the other hand, results of the SEEQ - based questionnaire [8] that we ask the students to answer every year.

Qualification list

Figure 3 depicts the overall numbers for the course. During the 6 semesters we have already offered it, we had 2 “pilot” semesters in which the number of students was limited. This allowed us to implement the design in a “controlled environment”. After that, each year, we have a semester with a high number of enrolled students (>200 in Spring) and another one (Fall) where we only have students who have missed their cohort.



(a) Evolution in number of students per semester



(b) Number of failures and Fail ratio

Figure 3

It is easy to deduce that the most relevant semesters to study are 3 and 5 (corresponding to Spring 2011, Spring 2012). This is also supported by the fact that semesters 1 and 2 (Spring 2010, Fall 2011) had none students failed mainly due the fact that, as they were the first cohort, both, students and faculty were highly motivated, professors also act as students, working with their groups, and achieved a high level of performance. The first steady-state semester was 3, when the number of failures was 14 and the failure rate 6%, still under the average failure rate of other courses (20-25%). Notice that, this failure rate have reached a standard value in semester 4 (Fall 2012), and that this value became stable since then.

To analyze the distribution of qualifications during all this 6 semesters we present Figure 4. We have divided the qualification range (1-10) in different sets and group students according to their qualification. We show how students in average have a good qualification (around 6-8 over 10). It seems clear that student should not find difficult to pass the course although it is very hard to get an outstanding qualification. The group of 8-10 qualifications decreases as we reach the steady-state semester, and is lower in the fall semester (students with overall lower qualifications in all the courses). We have broadened the range of given qualifications providing a more accurate way of classifying the students’ performance.

SEEQ – based questionnaires

In order to know more about the perception of the students with respect to the course, we ask them to answer a SEEQ-based questionnaire which includes the following questions (Meaning 1 the less and 5 the highest score). Results are presented in Figure 5 for the relevant semesters.

Q1. My interest in the subject has increased as a result of this course.
Q2. I have learned and understood the contents of this course.

Q3. I have progressed significantly in achieving the generic skills defined for this subject
Q4. The objectives of the course are well defined
Q5. The use of ICT tools has improved my learning process of the course
Q6. Assessment corresponds to the purpose and level of the course
Q7. The level of demand for this subject compared to the same quarter was (1. Much below 5. Much higher)
Q8. On average the hours of autonomous learning of this course are:
1: less than 3 2: range 3 to 5 3: range 5 to 7 4: range 7 to 9 5: More than 9 (hours)
Q9. Overall I am satisfied with this course.

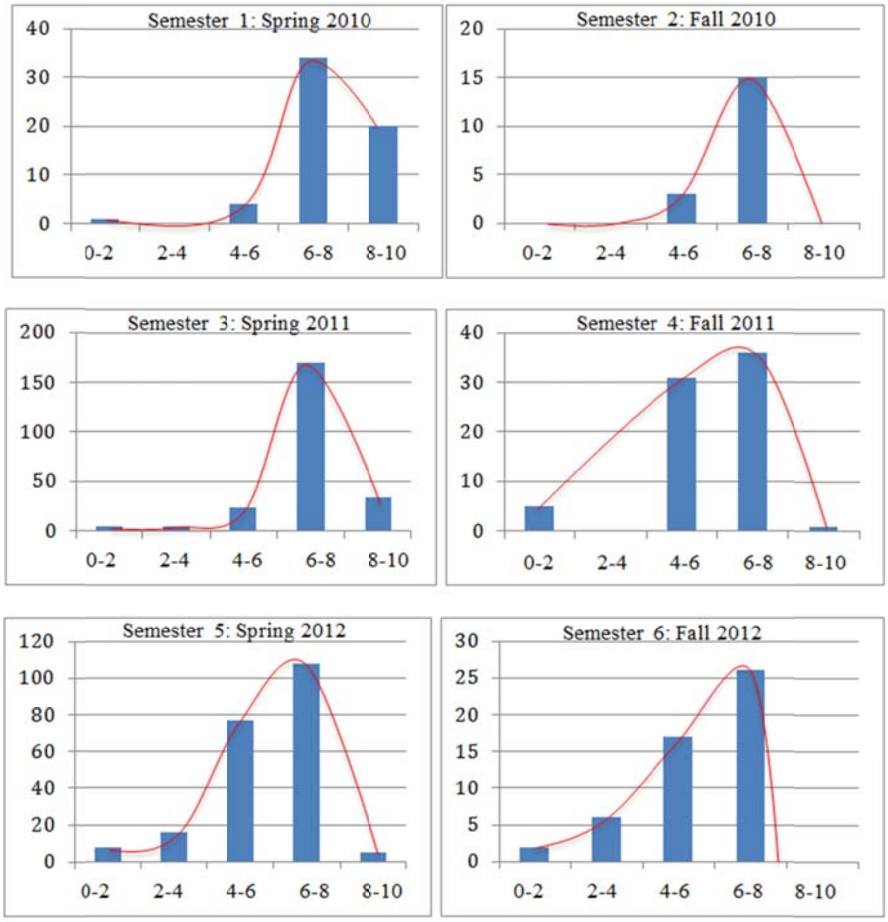


Figure 4 Histogram of qualifications per semester

The SEEQ-based questionnaire results show that the course is positively evaluated by the students. The results indicate the need to improve the course objectives definition (Question 4) which is particularly difficult given the wide scope of a project oriented discipline. In fact the course organization is being internally assessed by the teaching staff at the beginning and end of every term resulting in continuous improvements in all relevant aspects. This is reflected in the questionnaire results which shows better scores in Spring 2012 with respect to Spring 2011.

5. CONCLUSIONS

ENTIC, the Introduction to the Engineering course in the CDIO based ETSETB-TelecomBCN degrees curricula was first launched in 2010 and have already been offered six times at this moment. Since its preliminary design, it has undergone significant changes that result in a better operability and scalability, appropriate for a 300 student s per year course.

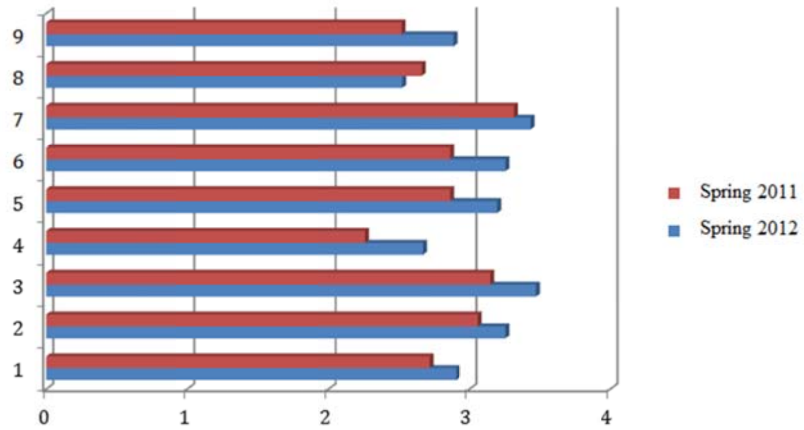


Figure 5. Results and evolution of the SEEQ-based questionnaire for the course

The course is project oriented addressing technical, organization and team work aspects. Delivering the course in the first academic year of Telecommunication Engineering studies is difficult due to the lack of technical background of students. On the other hand the course allows an early training of students on solving engineering problems, autonomous learning and project management.

Effective organization and assessment of the course including 3 different tracks with lectures, student document deliverables and public presentations, and laboratory work is a challenge for the teaching staff. For these reasons the presented course is periodically subject to internal assessment and improvements.

In this paper we have briefly described how this course was first implemented and detailed how it has evolved to its current state. The evolution of pass rate stabilizes to around 6-8 over 10 which is in average a good qualification but not optimum, and the failure ratio tends to 20%. This could be due to that despite the explanations given at beginning of the course about different activities to carry out (in different tracks) during the course and that the students know how these activities are considered in the assessment (formula to mark the course); students not give importance to activities outside of laboratory. Also commenting that the general impression is that students are very active during the first part of the project but practical problems in lab can provide a feeling of defeat and leave other activities. In order to overcome this disadvantage and so to increase the pass rate, more connecting bridges between three different tracks have been introduced for linking the activities in all tracks with the project developed in the lab.

On the other hand, students' satisfaction degree is high; in particular it is interesting to note that they consider with high score that the assessment corresponds to the purpose and level of the course (Q6) and that they have progressed significantly in achieving the generic skills defined for this subject (Q3). The result encourages to follow improving the course to bring students to their professional future environment at this early stage of their education.

REFERENCES

[1] CDIO Webpage. Conceive Design Implement Operate.
Available at http://www.cdio.org/ Last access Jan 2013

[2] Crawley, E. F., Malmqvist, J., Östlund, S., Brodeur, D. “Rethinking engineering education: the CDIO approach”. Springer, 2007.

[3] Bragos, R., Alarcón, E., Camps, A., Pegueroles, J., Sardà, J., Sayrol, E., “Conceiving and designing an ‘Introduction to Engineering’ course within the new curricula at TelecomBCN, UPC Barcelona,” Proceedings of the 6th International CDIO Conference, École Polytechnique, Montréal, June 15-18, 2010.
Available at http://www.cdio.org/files/document/file/T4C_Paper_2.pdf. Last access Jan 2013.

[4] Information of ENTIC in the ETSETB-Telecom BCN website.
Available at https://www.etsetb.upc.edu/documents/guia_docent/assignatures/SisAud/230009.pdf
Last access Jan 2013

[5] The Sea Perch Program webpage.
Available at http://seaperch.mit.edu/ Last access Jan 2013

[6] Krysander, C., “LIPS is a Project Model”, 2005,
Available at http://www.liu.se/cul/resurser/lips?l=en Last access Jan 2013

[7] Biggs, J. & Tang, C. 2007, Teaching for quality learning at university : what the student does, 3rd edn, Society for Research into Higher Education & Open University Press, Buckingham

[8] Marsh, Herb W. "SEEQ: a reliable, valid, and useful instrument for collecting students'evaluations of university teaching." *British Journal of Educational Psychology* 52.1 (1982): 77-95.

BIOGRAPHICAL INFORMATION

Josep Pegueroles, Ph.D. is associate professor at the Telematics department of UPC. His current research focuses security for multimedia networked services and secure group communications. He teaches at Telecom BCN.

Ferran Silva Ph.D. is associate professor at the Electronics Engineering department of UPC. His current research focuses on electromagnetic compatibility. He teaches at Telecom BCN.

Esteve Pallarès Ph.D. is associate professor at the Telematics department of UPC. His current research focuses on security and reputation in mobile networks. He teaches at Telecom BCN.

Sergi Bermejo Ph.D. is associate professor at the Electronics Engineering department of UPC. His current research focuses in electronics. He teaches at Telecom BCN.

Antoni Broquetas Ph.D. is professor of the Signal Theory and Communications department. His current research focuses radar, imaging and remote sensing. He teaches at Telecom BCN.

Ma Jose Soneira Ph.D. is associate professor at the Signal Theory and Communications department department of UPC. His current research focuses optical communications.

Corresponding author
Dr. Josep Pegueroles
Universitat Politècnica de Catalunya
CAMPUS NORD C3-308
c/ Jordi Girona 1-3
08034 Barcelona
Josep.pegueroles@upc.edu