PBL ACTIVITY AS LINK ELEMENT IN THE BACHELOR'S DEGREE IN INDUSTRIAL ELECTRONICS AND AUTOMATION ENGINEERING

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ABSTRACT

This paper describes the experience carried out within the Bachelor's Degree in Industrial Electronics and Automation Engineering taught at the Eastern Barcelona School of Engineering (EEBE) of the Technical University of Catalonia–BarcelonaTech (UPC). Specifically, the experience is based on the realization of a cross project that is under the framework of the degree intensification named *Application Design in Electronics Engineering* (ADEE). This intensification, consisting of a block of two courses, taught in the Fall and Spring semesters, and offered for students in their final year, allows the fulfillment, for two semesters, of the aforementioned project. This includes the design, simulation, implementation (assembly), testing and experimental results (corroboration) of an electronic system or equipment within the field of Electronic Engineering.

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1 INTRODUCTION

As is well known, technical studies, especially those concerning engineering, require a highly recommended (and, indeed, almost necessary) practical aspect. It serves not only as main key from a practical point of view of this typology of University degrees, but also it can be used as a motivational tool to current students and future engineers. The idea of cooperative learning-based activity that is shown in this paper started as a result of the detection by course professors of a lack of students' motivation and academic level and ability the Bachelor's Degree in Industrial Electronics and Automation Eng. In particular, this degree, which started in September 2009, was launched along with the Bologna Process. It is offered at the Eastern Barcelona School of Engineering (EEBE) of the Technical University of Catalonia (UPC) in the European Higher Education Area (EHEA) framework.

This lack of students' motivation, stimulation, encouragement, academic level and ability was not only detected at first level courses, where sometimes the motivation is limited due to the large number of common courses to be taken, but also (and worse) in students that are finishing their studies in Industrial Electronics and Automation Engineering and courses related to their own specialty.

The detection of this problem led to Professors of elective courses (taught in 4th year) of this Bachelor's Degree to implement an experience object of this article. This experience covers the fourth last-year course of the aforementioned degree intensification, named *Application Design in Electronic Engineering* (ADEE), which has the current degree. Indeed, these low expectations have led professors of these intensification elective courses to carry out different activities in recent years, including those related to cooperative learning and project-based learning (PBL). These activities could motivate alumni and make them interested in the contents of the mentioned courses, including those of the aforementioned ADEE intensification.

2 GUIDED ACTIVITY (GA) AT THE EASTERN BARCELONA COLLEGE OF INDUSTRIAL ENGINEERING (EEBE)

At the EEBE, current curricula courses are divided into 6 ECTS biannual courses, except for some very particular courses. As a consequence, a 6 ECTS course, especially those that are part of the degree specialty (core or elective), has their structure divided into the following four blocks:

- 1.2 ECTS credits for lectures (corresponding to 2 h/week).
- 0.6 ECTS credits for classes concerning problems (corresponding to 1 h/week).
- 0.6 ECTS credits for laboratory sessions (also corresponding to 1 h/week, but grouped into fortnightly sessions of 2 h).
- 3.6 ECTS credits of non-presential off-site (NP, or non-classroom) activities, and guided activities (GA) (corresponding to 6 h/week).

It can be seen that good workload involved in a particular course, and that students must perform throughout the semester, is framed within 3.6 ECTS credits for non-presential off-site activities (NP), and guided activities (GA). In general, in these credits, course students must perform activities, tasks, works, etc., relating, among others, to the following points:

- Making activities, problems, etc., concerning topics explicitly explained or not by course professors in lectures, problems and/or laboratory session.
- Research, development and/or preparation of activities by students of some topics that are not explained in lectures by course professors.
- Writing laboratory reports.
- Implementation of physical prototypes of electronic circuits, systems or equipment within the field of industrial engineering that is being considered in the course throughout the semester.

Concerning undergraduate studies in Industrial Electronics and Automation Engineering, within this workload of guided activities, special emphasis is focused on the design, simulation, physical implementation and laboratory test of a prototype electronic circuit, system or equipment. Indeed, all this process involves different stages which refer to all the actual process of developing electronic systems or equipment in an industrial or professional environment that students will encounter in a near future in their professional career:

- Design of the different single blocks of the electronic circuit, system or equipment to be carried out.
- Simulation of the aforementioned blocks individually, and simulation of the complete set when they are interconnected.
- Physical implementation of the aforementioned individual blocks that form the system that should be implemented.
- Testing of these individual blocks and experimental corroboration of their operation.
- Assembly and installation of the blocks in order to obtain the complete system or equipment.
- Test, experimental corroboration and obtainment of experimental results of the complete system or equipment carried out.
- Creation of a technical report covering the entire process carried out, simulation results, experimental measures, cost estimation, etc.
- Oral dissertation, within a limited time, of the carried out cross project.

3 COURSES RELATED TO ELECTRONIC SYSTEMS IN THE BACHELOR'S DEGREE IN INDUSTRIAL ELECTRONICS AND AUTOMATION ENGINEERING AT THE EEBE

Within the Bachelor's Degree in Industrial Electronics and Automation Engineering at the EEBE, courses that refer to the study of electronic systems are shown in Fig. 1. Bachelor’s students begin in the Electronic Engineering area in the 3rd semester. In the 6th semester, the degree continues, among other subjects, with Analog Electronics, which allows delving, as similar to the previous one in the digital area, in this case into the analysis and design of analog electronic circuits, mainly based on the operational amplifier. Once passed this semester, in the 7th semester, students enter the phase of elective courses, in which they should choose five 6-ECTS subjects (the current curriculum includes a total of 30 ECTS credits for elective courses). Finally, for undergraduate student, the Bachelor's Degree in Industrial Electronics and Automation Engineering at the EEBE ends with the development of the Bachelor's Thesis (BT) during the 8th semester.

This paper focuses on one core (compulsory) course and one elective courses shown in Fig. 1: ***Analog Electronics*** (EA-EIA), and ***Implementation of Arduino-Based Acquisition Systems*** (ISABA). However, it is also important to highlight that each of the two courses are considered «self-contained». Therefore, the order in which students can take them is not significantly important.

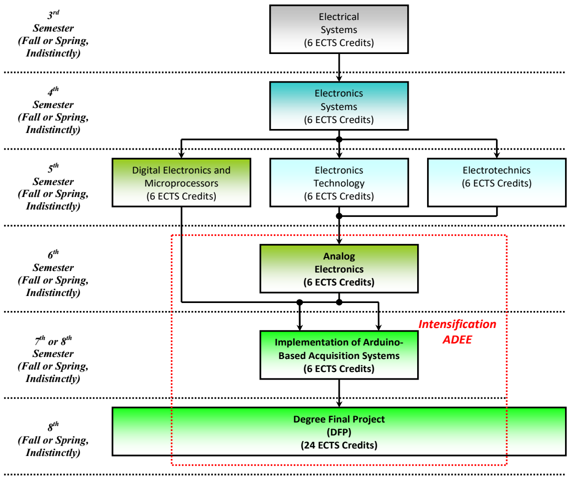

Fig. 1. Map of courses in the field of Electronic Engineering and degree intensification Application Design in Electronic Engineering (ADEE) for the current curriculum of the Bachelor's Degree in Industrial Electronics and Automation Engineering taught at the EEBE.

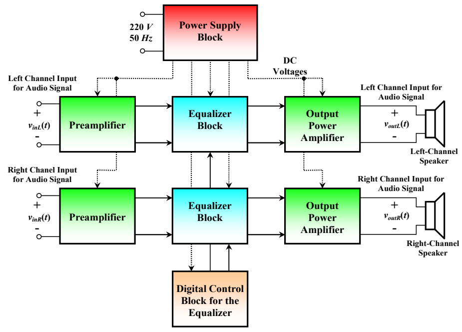

Fig. 2. Overall block diagram of the equipment to carry out in the cross project.

4 EXPERIENCE CARRIED OUT IN COURSES UNDER STUDY

As already mentioned, the idea of cooperative learning activity that is set out in this paper starts when low academic results are observed by degree staff since the introduction of the current curriculum level in September 2016. These course students' low academic results worry and even alarm lecturers, especially because they are in core courses of the Bachelor's Degree, just before ISABA course. Moreover, in recent years, these low expectations have led professors of different elective courses in Electronics area, to consider different activities, including those related to cooperative learning and project-based learning (PBL) to motivate alumni and make them interested in the contents of the mentioned courses, including the subjects included in the aforementioned intensification ADEE.

This paper focuses on what the authors have called "***cross project***" as part of the GA activity. This cross project is included in the two courses previously mentioned (and, obviously, their materials) that define such intensification. To carry out this cross project, it is required that mind-preferred (although not essential), undergraduate students enroll in these two 6-ECTS courses; compulsory course (EA-EIA) in the Fall semester, and the elective course (ISABA) in the Spring. Thus, they can obtain 6 ECTS credits of a total amount of 30 ECTS required to complete their Bachelor's Degree. The activity focuses on the development (which includes the design, simulation, implementation, testing and experimental corroboration) of an audio equipment based on the following five blocks (Fig. 2): Audio equalizer stage, audio preamplifier stage, audio power amplifier stage, digital control module for the equalizer stage and power supply subsystem.

In particular, focusing on the experience on which this paper deals, the activity under study mentioned before consisted of all the process (design, simulation, implementation, testing and experimental corroboration) conducted. To do this, this is carried out in face-to-face sessions, where lecture (2 hours/week) and problem (1 hour/week) sessions are merged in a single 3-hour weekly session. Thus, the cross project is divided into the two semesters (Fall and Spring) mentioned above.

5 PART I OF THE EXPERIENCE CARRIED OUT (COURSES IN FALL SEMESTER)

As a first step in the realization of the cross project during the Fall semester, advanced the course ***Analog Electronics*** (EA-EIA), detailed guidelines (that is, design specifications) of said equipment are presented in class (required output power, frequency bands working, input and output impedances, etc.). From these specifications, and from week 10 of the course (remember that the academic semester includes 15 weeks), in parallel with the progress of this first course, students also advance in the design of part of the different blocks that constitute the system. In particular:

- The design, simulation, assembly, testing and experimental corroboration of the equalizer stage. This process includes the design and calculation, simulation (by means of OrCAD-PSpice®), etc., of the different cells that form the required equalizer.
- The same process for the preamplifier stage is performed. This serves as a support for the student to do the transistor level simulation of such blocks based on the initial design specifications (simulation of the operational amplifier used in different sub-blocks, simulating the preamplifier stage performed around this operational amplifier, etc.). In addition, the student implement theoretical knowledge explained in theory classes.

During the final five sessions of the course, they (considering 3-hour classes) were divided into different parts:

- The first session (that never exceeds 50-55 minutes) has been devoted to explaining (through lecture) those theoretical contents that the course professor must develop so that students can delve into the different topics required for the proper development of the cross project. Students, in this first hour, had a passive role, listening and note-taking or, where appropriate, monitoring the corresponding transparencies previously delivered to them.

- Then, in the next two hours of the session, students, in groups of three, worked on the stages design, simulation or/and assembly directly linked with the theoretical stage explained by the professor in the 1st hour of the session.

In general, the time available in the last five weeks of the course is insufficient to carry out all the process design in class. However, it is important to highlight that this cross project is framed within the non-attendance of the course workload. Therefore, course students should continue working in it outside the classroom, as part of the 3.6 ECTS credits that correspond to non-presential off-site activities and guided activities (corresponding to 6 h/week) referred to both courses. This Fall course ends with two full prototypes developed by the working group (Fig. 3):

- First, the design, simulation, implementation, and testing of the experimental audio equalizer stage.
- In addition, the design, simulation, implementation, and testing of experimental preamplifier stage.

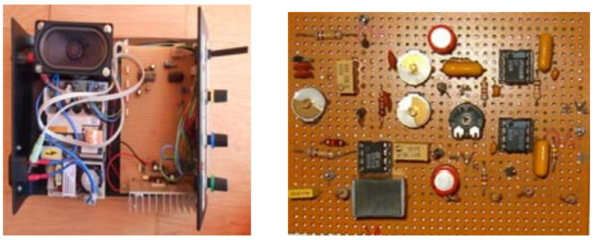

Fig. 3. Examples of different prototypes of some of the partial blocks implemented by students.

In addition, depending on the number of students enrolled in the course, some semester, course professors have also opted for a 15-minute oral presentation. With this presentation, every group can present the work they carried out to course professors, and their classmates.

The project ends this semester transiently with a numerical score which is incorporated into the course EA-EIA of this semester. The weight of this part in both courses is 30% of the total.

Note that each block of the implementation could be self-contained (an amplifier stage, for example, is already a system that allows to be used in many applications). However, the student should keep the key idea that this block is part of a more complete system, whose objective goes beyond that one of these single courses. Notice that here, the idea of globalization, content integration and course coordination are key.

6 PART II OF THE CARRIED OUT EXPERIENCE (COURSES IN SPRING SEMESTER)

In this case, the courses where it continues with the realization of the cross project consist of the elective course of the ADEE intensification taught in the Spring semester: ***Implementation of Arduino-Based Acquisition Systems*** (ISABA).

The mechanism, procedure and routine of the courses are similar to the first one taught in the Fall semester: In the first sessions of each course, the cross project remains stopped, and theoretical and practical elements and contents of both courses evolve. Then, from week 10 on, approximately, students pick up the project with the realization of the missing blocks to complete the overall system:

- The design, simulation and assembly of the digital control stage for tuning the audio equalizer is performed. It serves as support for the student to perform the

design, simulation and implementation of control system for the equalizer stage implemented in the previous semester.
- The design, simulation and assembly of the power amplifier stage, and the power supply subsystem of all equipment is made. It serves as support for the student to perform the design, simulation and implementation of the power amplifier stage and power supply that provides power for the entire equipment.

Thus, when optional ISABA course ends, in a similar way that in the compulsory course EA-EIA, with two full prototypes made by the working group:

- On the one, the design, simulation, implementation and test stage of a digital control sub-block for the audio equalizer, developed in the course EA-EIA.
- In addition, the design, simulation, implementation and testing of the power amplifier stage and power supply subsystem carried out in the course EA-EIA.

7 PART III OF THE CARRIED OUT EXPERIENCE (COURSES IN SPRING SEMESTER)

Completed the two semesters (Fall and Spring) and, therefore, having made the student group's cross project framed in the two courses under study (EA-EIA, and ISABA), finally, to overcome the activity and finish it, the students' groups must:

- Assemble the different circuit blocks that make up the complete prototype of the overall project.
- Test of the global equipment in the course laboratory, taking appropriate experimental measurements of the whole, corroborating the proper functioning of the whole system.
- Submit a technical report that highlights everything done in relation to the cross project along the four courses (detailed explanation of the project, process design, simulation and experimental results, etc.).
- Present the project to the group of professors of the four courses as well as the set of classmates.

The project ends with a numerical score. This mark is incorporated into the ISABA course. The weight of this part in the subject is 60% of the total.

8 EVALUATION AND CONCLUSIONS OF THE CARRIED OUT EXPERIENCE

Regardless of qualifications, to assess the activity, information reported by the ‘affected’ people (i.e., course students) was used. It is important to highlight, after several detailed talks subsequent to the presentation and defense of the cross project, the good reception of the experience by students. For the article authors, this aspect is very important, even though, in some groups, results and marks were not fully satisfactory (marks below 7 on a total of 10 points).

For most students, it was not the first time that they performed an evaluation experience of this kind. In fact, in different core courses exposed in Fig. 1 (e.g., Analog Electronics), a part of the course includes the design, simulation, implementation, and experimental corroboration of the operation for a more limited circuit. In them, the goal is that the circuit has a well defined purpose, within the scope of the course itself, but its magnitude is generally dimensioned so that the same dedication from the student is limited. In this case, however, the cross project has a much larger dimension. In addition, it is contained in different courses that, although they are in the same area, they deal with different topics within the field of Electronic Engineering.

However, despite the difficulty and great dedication that students said in their opinion of the course, they expressed a number of strengths of the activity. From these collected opinions, three should be emphasized:

- For students, the proposal of the cross project resembles projects that would take place in a company by a group of engineers. This put the involved courses, and their contents (and, of course, especially, the degree) closer to the imminent actual professional world for these students.
- The *cross project* removes the «tightness» that currently have many courses taught in Spanish University. Our undergraduate students often see the degree courses as separate from other courses. This separation is perceived not only for courses in different semesters, but even for courses taught simultaneously in the same semester. They find it difficult to integrate and globalize different degree courses (core or not) in a common framework of the degree. According to students, the cross project largely eliminates this sealing. As mentioned here before, the idea of globalization, content integration and coordination in the cross project is key point.
- It allows students to focus their Bachelor's Thesis (BT) on a topic close to the cross project or close to contents of the courses included in the intensification that serves as framework for the transversal project. This idea is also a key point to many students who are intensifying as a way to focus their careers in a certain area within the wide field of Electronic Engineering.

Finally, as future research by part of the coauthors of this study, we want to make a series of progressive improvements in the carried out procedure, which involves the following points:

- Mount the cross project as a learning system based on project-based learning (PBL) by technical puzzle. This will imply considering a greater time commitment within the course to carry out the project (sessions will be needed to make the expert meetings, to take time for explanation of an expert to the other members forming the group, etc.). However, in the article authors' opinion, it will result in an improvement from the point of view of learning.
- Conduct a peer assessment set by the students enrolled in the course. Until now, assessment has been carry out by the course professors involved in the project. It is not excluded, however, that part of the final grade of the cross project is carried out by course students themselves.
- Open the project presentation to students of previous semesters, in order to see what advanced students of the same degree have done. This would undoubtedly incentive and motivate these students less advanced, who would firsthand see the «applicability» of their Bachelor's Degree.

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