

# **SUBSTITUTE YOUR LECTURES BY COOPERATIVE PROBLEM-BASED LEARNING (PBL) SESSIONS**

Francesc Josep Sànchez i Robert

*Escola Politècnica Superior de Castelldefels (EPSC), Universitat  
Politècnica de Catalunya (UPC), Departament d'Enginyeria  
Electrònica (EEL)*

*Francesc.josep.sanchez@upc.edu*

## **Abstract**

This paper shows examples of assignments, which have been redesigned in order to centre teaching in the student's learning, which is one of the requisites of the EHEA. Our approach has been to teach content through the use of some cross-curricular skills: teamwork, autonomous learning, and effective communication.

## **Workshop Topics**

*Autonomous learning, beyond active learning*

## **I INTRODUCTION**

Digital Electronics (ED) is a compulsory subject included in the selective phase (the first two semesters) of the Bachelor's degree in Telecommunications Engineering of the Escola Politècnica Superior de Castelldefels (EPSC) of the Universitat Politècnica de Catalunya (UPC). ED was reorganised since 2002/03 to replace traditional lectures by an active student-centred learning approach where techniques as cooperative learning (CL) and problem-based learning (PBL) played a major role [1]. ED web pages [3] which are like a course portfolio contain all the relevant data and materials.

The cooperative learning (CL) method differs substantially from the classical, passive lecturing approach in which students merely take notes through the class, while watching and listening to the professor. The latter represents the old paradigm of teaching, as Johnson, Johnson and Smith [5] stated, while the former represents a new paradigm of teaching with many advantages that can produce a great improvement to the learning process. In the classical method of lecturing, which is predominantly in use at UPC, a student learns in isolation, in competition with his or her colleagues. The cooperative approach represents a real change in the way teaching and learning is being conducted at the school. Furthermore, course's content, which was traditionally the most important thing in the world, as everybody assumed, has to leave room so that other very important professional skills can also be learned (effective communication, teamwork, self-directed learning).

To make such a thing viable, learning content and cross-curricular skills, a PBL methodology [6] is applied to redesign every course task, and this paper will be focused in examples on how theory and problems classes and course materials were replaced by new activities and a better course organisation. To put the subject in this very specific context, Figure 1 and Figure 2 show first year major names and ED course syllabus.

	HT 3	HA 1	HT 4	HA 2	HT 3	HA 1	HT 2	HA 2	HT 2	HA 2	HT 1	HA 2		
1A	<b>Fundamentals of Mathematics I</b>		<b>Fundamentals of Physics</b>		<b>Introduction to Computers</b>		<b>Electronic Devices and Circuits</b>		<b>Introduction to Engineering</b>		<b>Written and Oral Communication Techniques</b>			
	CT 4.5	CA 1.5	CT 6	CA 6	CT 4.5	CA 1.5	CT 3	CA 3	CT 3	CA 3	CT 1.5	CA 3		
1B	HT 3	HA 1	HT 2	HA 1	HL 1	HT 2	HA 1	HL 1	HT 3	HA 1	HT 2	HA 3	HT 1	HA 3
	<b>Fundamentals of Mathematics II</b>		<b>Probability and Statistics</b>			<b>Linear Systems</b>			<b>Digital Electronics</b>		<b>Electronics Laboratory</b>		<b>Software Laboratory</b>	
	CT 4.5	CA 1.5	CT 3	CA 1.5	CL 1.5	CT 3	CA 1.5	CL 1.5	CT 4.5	CA 1.5	CT 3	CA 4.5	CT 1.5	CA 4.5

Figure 1. Subjects of the selective phase consisting in semesters 1A and 1B of the first course.

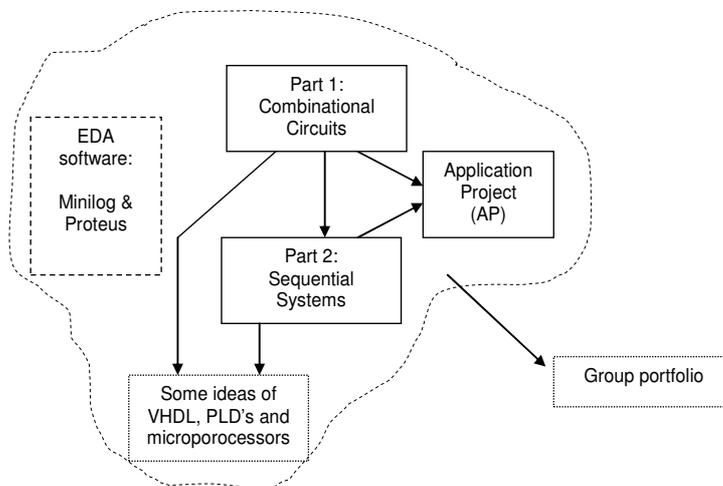


Figure 2. Course syllabus.

## II COURSE ACTIVITIES

### II.1 Description of a classic assignment

Let's try to introduce a pair of examples of the kind of exercises that were common in a subject like ED when taught in a classical way. They consisted, generally, of:

- A brief description of what to be done.
- No references to real world were given, no indications of which was circuit's purpose.
- Only result was important and marked.
- Prepared to be solved individually.
- No electronic design automation (EDA) tools were required as an aid to solve or self-verify problem's solutions.
- Easy to upload on a digital campus or course's intranet, and easy to answer electronically.
- A simple or a unique solution was possible, which meant easy or even automatic correction.
- Problem data was easy to be modified. Slight variations prevented student copying or cheating.

The idea was to develop a large set of such exercises in order to cover all the course content. Instructor's main aim was lecturing about how to solve these kinds of problems, and basically, they trained students to repeat procedures already developed in class. Thus, the course consisted of content-specific learning objectives, which were rated between the first ones in the Bloom's taxonomy (*remember*, *understand* and *apply* a procedure in a given situation) [2].

Many books on the subject have thousands of such pure academic exercises. Thus, instructors do not have difficulties in managing and administering them.

A couple of examples show the way these problems are presented:

- 
1. Chapter 1 exercise to learn about logic function minimisation.

*Design a circuit using NOR after representing on Karnaugh maps and minimising the functions described by the following expressions:*

a.  $G(x, y, z) = \prod M(1,3,4,7,10,13,14,15)$

b.  $K(x, y, z) = \sum m(0,4,5,9,11,14,15) + \sum dc(2,8)$

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2. Chapter 2 exercise example to learn about designing finite state machines.

*Obtain a canonical sequential system using flip-flops T for the state diagram shown in Figure 3.*

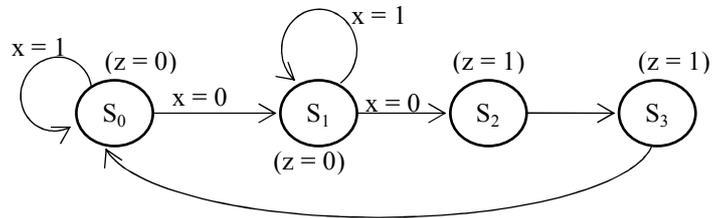


Figure 3. State diagram for the second example.

## II.2 The new PBL oriented assignments

Learning objectives have been enhanced to include some cross-curricular skills, which is the key to apply successfully the PBL approach using cooperative base groups [5] he whole semester.

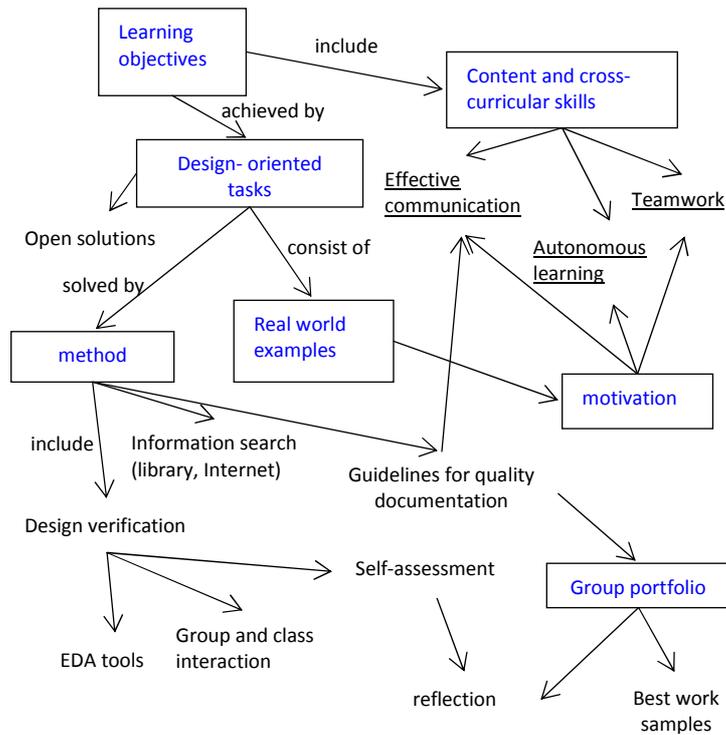


Figure 4. PBL and CL approach in ED course represents learning by doing in both theory and problem classes

A couple of examples show the way these PBL-oriented problems looks like:

1. Chapter 1 exercise to learn about logic function minimisation.

A storage tank system for a pancake syrup manufacturing company is shown in Figure 5. The control logic allows a volume of corn syrup to be preheated to a specified temperature to achieve the proper viscosity prior to being sent to a mixing vat where ingredients such as sugar, flavouring preservative, and colouring are added. Level and temperature sensors in the tank and the flow sensor provide the inputs for the logic. (...)

The complete assignment description and instructions can be found in:

[http://epsc.upc.edu/projectes/ed/ED/grups\\_classe/08-09-q2/1BT5/08-09-Q2-1BT5.htm](http://epsc.upc.edu/projectes/ed/ED/grups_classe/08-09-q2/1BT5/08-09-Q2-1BT5.htm) (MI2)

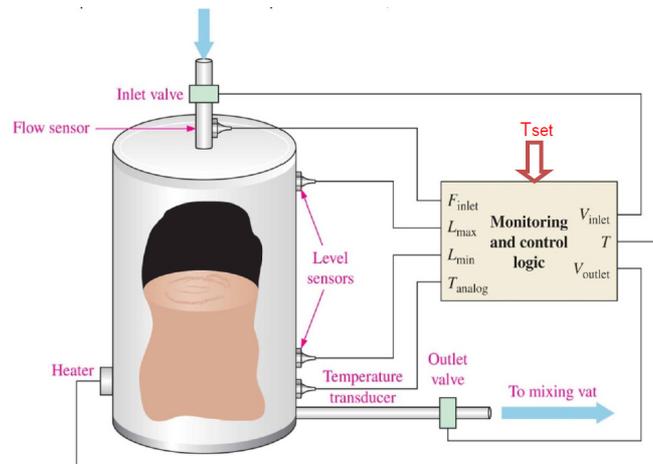


Figure 5. Sketch of the tank to be controlled with level and temperature sensors (from: Floyd, T. L., (2009). Digital Fundamentals, 10th ed. Pearson. Printed with permission from Pearson Education).

Exactly as in Section II.1, we pretend that students learn the content of Chapter 1 corresponding to logic function minimisation. However, in this case, they will be engaged in solving a *real world* exercise. This is a key point in trying to motivate them.

In addition to learning the content, we pretend that our students while working in groups:

- Read and analyse problem's description, and agree to gather extra information about all the auxiliary components. They can use Internet or the library (books, research papers and product application notes).
- Propose a solution for the problem which has to be supported by all team members.
- Distribute tasks or sections of the problem and solve them individually.
- Explain and teach each other until all group members comprehend the whole exercise.
- Agree in developing a verification process to demonstrate their solutions' validity.

2. Chapter 2 exercise example to learn about designing finite state machines.

*Design a simple asynchronous sequential system by the direct method to produce an OPEN/CLOSE control signal for a deadbolt as shown in Figure 6. The secret code to open the door is '39#'. (...)*

Full exercise instructions can be found in:

[http://epsc.upc.edu/projectes/ed/ED/grups\\_classe/08-09-q2/1BT5/08-09-Q2-1BT5.htm](http://epsc.upc.edu/projectes/ed/ED/grups_classe/08-09-q2/1BT5/08-09-Q2-1BT5.htm) (EX5)

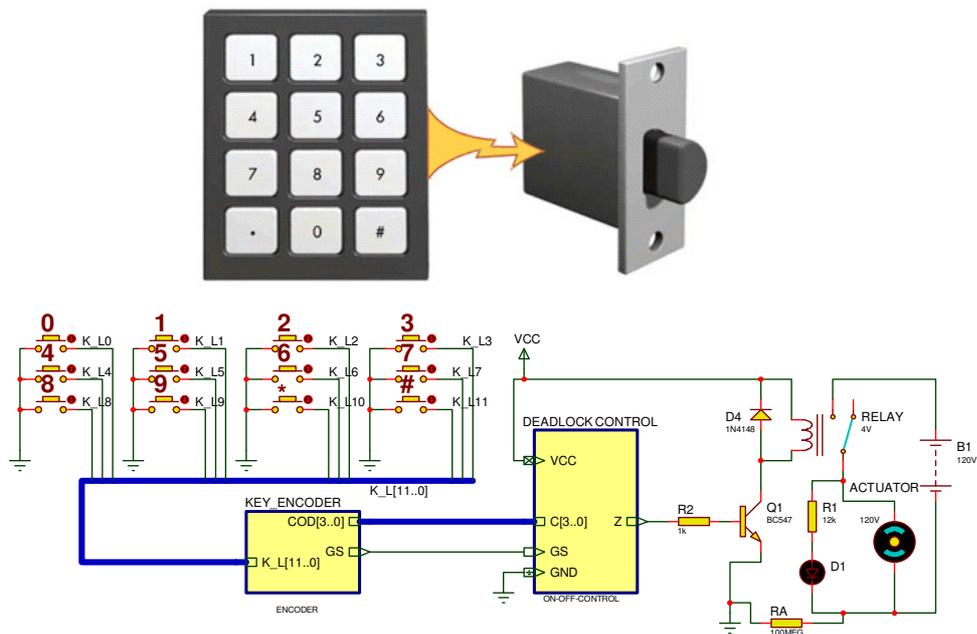


Figure 6. 1 Schematic for the system to be designed to drive a signal to control a deadbolt. (Upper image source: Ted Carmely, “Using Finite state machines to design software”, Embedded Systems design magazine, vol. 22, num. 4, April 2009. <http://www.nxtbook.com/nxtbooks/cmp/esd0409/#/18>)

In this second example of real-world problem, students, organized in base groups of three, have to: search for information; plan, distribute and develop the tasks; interact in and out of class; and obtain a solution which has to demonstrate that their circuit works satisfactorily in an electrical circuit simulator. Finally, they have to put together a written solution following instructions in a given template to assure its quality [7]. Solution must: reflect and give personal opinions on the problem or the course; calculate the study time devoted to the development of the problem (ECTS); and sign a fairness statement. This is our way to focus all the learning in the *process* of engineering products, and give us the opportunity to apply once and again the scientific method.

These are the kind of problems which will guide and pace the learning through the course. Practically, all the course activities are oriented in developing the proposed problems:

- Short presentations adjusted to the problems content have replaced classic lectures of *theory*. Virtual laboratories where everything that is being designed has to be verified have been possible using portable computers in class.
- Open solutions for problems, means that every cooperative group can develop a different solution which may also *works* and possibly be correct. Consequently, it is not difficult to organize puzzles, or other class techniques to allow students contrast and compare circuits with similar features.
- Individual exams, the *minimums*, check if really effective cooperation takes place among team members, so that positive interdependence succeeds: students have two responsibilities: 1) learn the assigned material, and 2) ensure that all members of the group learn the assigned material.

### 3. An application project example

*Design a digital clock like the one shown in Figure 7 in which time is represented in the classic digital format HH:MM:SS using 7-segment displays.*

The development of this task is available at:

[http://epsc.upc.edu/projectes/ed/ED/grups\\_classe/07-08-q1/1BT4/07-08-Q1-1BT4.htm](http://epsc.upc.edu/projectes/ed/ED/grups_classe/07-08-q1/1BT4/07-08-Q1-1BT4.htm) (EX7)

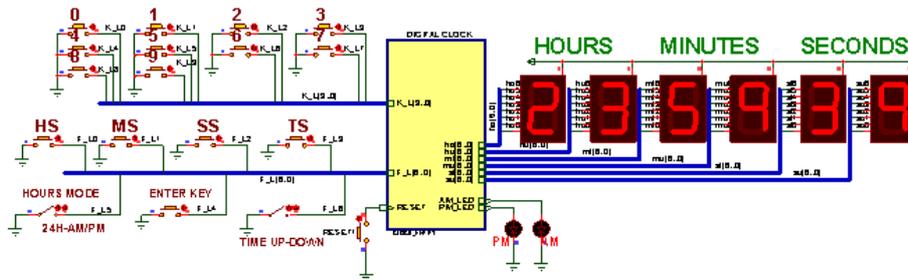


Figure 7. A digital clock with a keypad and 7-segment displays

Application projects imply integrating content already developed throughout the course. They can be considered as large task which can be divided in many sections. Each one of these sections or modules can be considered as regular exercises. The point here is that students must have to structure the problem autonomously, applying their previous experience when solving regular exercises. Sometimes, a project can be assigned even to up to eight different cooperative groups. In this way the class has to collaborate altogether in achieving a final result. A professional environment can be recreated in this way.

Besides, projects have to be presented using slides, thus all the class can participate in the discussion and in the assessing process using an oral presentation rubric.

### **III DISCUSSION**

Similar or even exactly the same assignments can be easily placed in following courses with the goal to solve them using a better and up-to-date technology such as microcontrollers ( $\mu$ C) or field programmable gate arrays (FPGA).

Written solutions and oral presentation and reflections may become evidence of student learning through the course. They are integrated in the ED group student portfolio, and they could be used later as work samples for the EPSC student competency portfolio [4], which is focused in demonstrating the cross-curricular skills: teamwork, work by projects, effective communication, and autonomous learning .

The new method has a serious drawback which can be a burden for teachers who want to start a similar approach: that of imposing a considerable initial workload for the instructors, estimated to be more than 2 hours for each hour of lecturing. Even after the experiment has been set up, the major changes have been in place, and a new set of documents has been developed during the first semesters, CL and PBL still require more time than the traditional lecturing method, essentially due to the large amount of material to be regularly graded and delivered back to the students. It is easy to understand: having to assess content and some cross-curricular skills is more difficult than to be concerned in content only.

### **V CONCLUSIONS**

Classic lectures based on content and problems or laboratory sessions are not adequate any more when regarding the new set of requirements settled by the EHEA. Especially when thinking that students must be able to learn not only content but also a set of cross-curricular skills. This paper describes examples on how typical classic assignments can be rewritten completely with the aim of guiding all the learning through the course. Teaching using such as new exercises, successfully promotes a student-centred environment which develops teamwork, communication and autonomous learning skills.

The key point is to introduce student autonomy in stages depending on the students' experience gained through the studies. Even in a single course, activities have to be paced so that students will start with instructor-guided problems, and end with problems planned and scheduled by the students themselves. Student learning assessment has to be continuous, formative and embedded into the task, therefore, there is no room left for classic final exams, which is of great satisfaction and relief. Exams have always been a source of never ending problems, discouragement and mistrust between students and instructors.

The author firmly considers the method highly effective in introducing the teaching changes required to adapt university studies to the requirements of the European Higher Education Area (EHEA).

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