# THE FIRST TIME ON THE OTHER SIDE: PHD CANDIDATES EXPERIENCE IN DIGITAL ELECTRONICS PRACTICAL SESSIONS AND FINAL PROJECT

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## Abstract

The university Lecturer Training Fellowship granted by the Spanish Ministry of Education implies the participation of the PhD candidates in the practical lessons of subjects related to their specialty. For the first time, two students were assigned to the high performance group in Digital Electronics in the Industrial Electronics and Automation degree, taught in the School of Design Engineering (ETSID) of the Universitat Politècnica de València (UPV).

Taking advantage of the PhD candidates' easiness for comprehending the student's point of view, they were allowed to suggest and implement methodological modifications with the aim of improving the knowledge and skill transfer in the subject field.

The main result was the development of a methodology which relates the practical and theoretical parts so they are interleaved, making it easier to comprehend, assimilate the concepts, and participate actively in the practical part gaining experience in the field. The subject is divided in three main parts: VHDL, microcontrollers and a final project. One of the PhD students was assigned to the VHDL part, the other one to the microcontroller part, and the final project was collaborative, with both participating in the organization and evaluation.

This final project evaluates the innovation, creativity and entrepreneurship transversal skills of the students by entrusting them to develop a microcontroller code and to write the documentation about it, while participating in a car-like robot competition. This year, the competition was presented as a list of requirements the robots must meet before the deadline to access the "final test", in a way that was first implemented by the successful aerospace company SpaceX for the international Hyperloop Pod Competition series. This makes the deadlines and evaluation items very clear for both students and evaluators while leaving the door open to different ways of implementation using the knowledge acquired through the semester.

This paper presents the thought process behind the methodology used during the subject and final project and the results obtained, alongside with the experience reported by both students and PhD in-training candidates.

Keywords: competence, evaluation, training, experience.

## 1 INTRODUCTION

The engineering studies have on the highest update rates of all fields: technological and scientific improvements make the teaching content out of date in short-term, making their updating a necessary constant to keep the capacity to prepare professionals adapted to the new reality and the needs of the permanently changing industry. This update-rate is even more acute in the electronic engineering field.

The high update rate of teaching content means that teachers no longer teach the content they learned from scratch, to the extent that it can be considered other content that they have learned from a more advanced base. Learning a content from a different base makes them identify in a different way the hardest points to learn, so the inclusion of recently graduated teachers to adapt the teaching methodology could improve the learning-teaching process by taking advantage of their greater facility to identify the most complicated corners to cover with the current methodology and propose alternatives to fill such edges.

With this purpose, the PhD candidates collaborated in the teaching of the high performance group of Digital Electronics subject of ETSID, UPV, developing a new methodology which improved the knowledge and skill transfer in the subject field [1]. It is not the first time new methodological procedures are implemented and evaluated in this group, such as in the implementation of a car-like robot competition [2], academic assessment improved during this experience.

The results obtained from this experience state that the collaboration with recently egressed students as professors enhances the identification of voids and flows in the methodology and easies the improvement of the learning-teaching process.

# 2 SCOPE OF APPLICATION

## 2.1 The UPV

The Universitat Politècnica de València (UPV) provides high standard professionals for the wide variety of 40 bachelor's degrees, 80 master's degrees and 30 PhD programs, for which counts with 3,422 professors and researchers for its 30,750 students. All the degrees are based on the EHEA criteria, according to the best teaching practices in the apprenticeship of nowadays professionals [3].

This is reflected in the fact that the UPV is the first Spanish technological university in the Academic Ranking of World Universities (ARWU or Shanghai Ranking) [4]. Since its inception in 1969, it has been characterized as a university linked to the economic fabric from which it nourishes, providing professionals trained to the highest standards and adapted to the new demands of a modern and changing society.

These high standards are the result of, inter alia, the compromise with the teaching improvement and the use of learning-teaching processes in the classrooms at the highest level. In this line, the review and adaptation of the methodology in Digital Electronics is just another step forward with this direction.

## 2.2 The ETSID

The ETSID, nowadays, is a 4,000 students engineering school of UPV, which origins are in 1851 in "L'Escola Industrial de València" [5]. It counts with five bachelor's degrees and six master's degrees in which are applied the most modern methodologies in an environment of educational innovation to meet the needs of a constantly changing industry with excellently trained engineers in a technical and humanistic way. The excellent educational standards let the ETSID to be a reference school not only at the UPV but in the region.

## 2.3 The subject Digital Electronics

Digital Electronics is a compulsory subject in the second year (Semester B) of the Degree in Industrial and Automatic Electronic Engineering, corresponding to the training of Specific Technology "Industrial Electronics". This subject is taught after having studied the following subjects, which due to their contents have a greater influence on Digital Electronics: Computer Science (1st, Semester A) and Electronic Technology (2nd, Semester A) [7].

This experience is applied in the high performance (ARA) group of the university degree in Industrial Electronic and Automatic Engineering, which in the 2018-19 academic year is made up of 21 students, two of them being exchange students. The ARA group is characterized by being a small group with outstanding students in terms of academic qualifications, and all subjects are taught in English.

Finally, the course culminates with a project of free choice to be carried out in pairs, in which any of the technologies can be used, giving special consideration to the development of creativity, innovation and entrepreneurship, a transversal competence that has been evaluated [7], as well as teamwork, which is cemented during the laboratory practices.

# 3 THE EXPERIENCE

Relating classical digital electronics contents to current real application problems has been addressed by several authors [8,9], relating classical literature to FPGAs (Field Programmable Gate Array) based integrated circuits, PLDs (programmable logic devices) of greater complexity than those used as a didactic tool in this article.

The teaching-learning process has been modified year 2013-14 so that instead of consisting of theoretical lessons, whose content was reinforced with laboratory practices as well as with weekly telematic tests, it consisted on the learn-by-doing after a theoretical introduction, firstly with a simple guided example, and secondly with a task to be performed in-situ by the students. Once the students were confident with the tools and concepts taught that session, they were explained in depth. In addition to maintaining the evaluation method of the weekly tests, collaborative tests were introduced at the beginning of each weekly session to review the previous content, improving the emotional disposition to learning shared by the classroom gamification techniques.

One common problem brought from the PhD's experience in their student period is that, sometimes, the students leave a course with the feeling that they have learned how to solve a certain problem, that was repeated during the lessons and in the exams, just to pass the subject, while the reality is that they won't be able to identify the same problem in the outer world, or even solve it with just little variations.

Applied to this subject, it is easy to program a microcontroller to blink a light as long as the hardware and software given by one manufacturer makes it as simple as writing one or two lines of code: any electronics hobbyist can do it with little money and a 5-minute Google search. But there are several manufacturers in the market and each one has its characteristics and a different set of tools, not giving that easiness. A little talk with colleagues employed in the industry will output a completely different set. For most of manufacturers nowadays, two lines can solve the problem, but not the same two lines.

With this in mind, the objective of the proposed methodology was not to teach how to program a given model of PLD or microcontroller like in a kind of certification course, nor to use abstraction tools that only work for a set of models of one vendor, but to tell the reality lying behind and work a solution. In the end, the software is just the thing that makes the hardware work, and the vast majority of the market is not reinventing the wheel when it comes to hardware between models or manufacturers.

Based on the former, it was developed and specified a methodology (called theoretical and practical deductive methodology [1]), implemented during the year of the article, which included the following modifications by the PhD students:

1. The simplification of the hardware platform to increase the assimilation of generic practical concepts by the students.
2. The inversion of the order of the contents of the course, because it is easier to grasp for the high-level programming, which the students already know, and go downstairs, than starting from the unknown and escalating from there to the field they already know.
3. Shorten the initial theoretical introduction to just the content needed for the following to be more efficient in the learning-teaching process.
4. The content which is theoretically seen in depth at the end of a set of sessions instead of after each session, with the same purpose of no. 3. Seeing all the theory in depth at the end might allow time to unbind their practical experience of the first sessions with their theoretical part.
5. The establishment of clear evaluation items for the final project, in terms of achieving an objective or accomplish a requirement, encouraging creativity and the application of the knowledge acquired on the basis of being able to freely implement the solution that the student devises.

As stated before, the theoretical approach of each module is made in such a way that the explanation is useful or very close to the use in different microcontroller or PLD models. It is implied that consulting the manufacturer's manual for a specific model is more important than memorizing the practical content taught in the course, since this is the methodology followed as the future professionals and is one of the most important aspects that the recently egressed professors pointed out.

Furthermore, all the content seen in the subjected is applied in a project chosen and fully developed by the students, which was presented in the final evaluation day. The option offered by default is the participation in a car-alike robot competition: motorized wheeled devices with a set of sensors and a set of tests to perform as a competition between groups. The tests are:

- A line follower circuit to be circled in the shortest time possible.
- Avoiding obstacles.
- The same circuit but guided by the students using a remote controller.

Seeking for the improvement of this evaluation which is not new [2], the competition is presented as a list of requirements the robots must meet before the deadline to access the final test, in a way that was first implemented by the successful aerospace company SpaceX for the international Hyperloop Pod Competition series. This makes the deadlines and evaluation items very clear for both students and evaluators, using a checklist, as seen in Figure 1. The condition was that the group had to present a minimally working system before getting their robot to the test track.

| GROUPS | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| **DOCUMENTATION** | | | | | | |
| a) Report delivered | | | | | | |
| **TEST 1 LINE FOLLOWER** | | | | | | |
| a) Power-ON: LED LR_I blink OK, no movement | | | | | | |
| b) IR START Command, robot starts moving | | | | | | |
| c) IR STOP Command, robot stops moving | | | | | | |
| d) Robot can follow a minimal test track | | | | | | |
| e) Permission to get in the test circuit | | | | | | |
| f) Robot performs the test circuit well | | | | | | |
| g) Permission to get in the ciruict the competition day | | | | | | |
| h) IR START command OK | | | | | | |
| i) Completed the circuit in ________ seconds | | | | | | |
| j) Got out of the track ________ times | | | | | | |
| k) Needed help or got stuck ______ times | | | | | | |
| l) IR STOP command OK | | | | | | |
| **TEST 2 LABYRINTH** | | | | | | |
| a) Power-On: LED LR_I blink OK, no movement | | | | | | |
| b) IR START and STOP commands OK | | | | | | |
| c) Robot can detect obstacles and avoid them | | | | | | |
| d) Permission to get in the Labyrinth the competition day | | | | | | |
| e) IR START command OK | | | | | | |
| f) Got out of the maze in _______ seconds | | | | | | |
| g) Bumps _________ objects | | | | | | |
| h) Needed help or got stuck _______ times | | | | | | |
| i) IR STOP command OK | | | | | | |

*Figure 1. Part of the checklist and the points achieved by the groups after a few hours into the development.*

The next steps taken by this project is to allow the students participate later on the development of a new robot model for the subject. This serves both as a new way to fully develop their abilities in electronics design, implementation and programming, complementing the subjects they will be learning on the bachelor's degree, and to review the possible points of failure in the robot that makes the competition less desirable. The results of this experience will be assessed next year.

## 4 RESULTS

After the PhD students' suggestions, the structure of each thematic unit is:

1. Collaborative test as review of the already seen in class (*Who want to be millionaire?* alike).
2. Brief theoretical introduction.
3. Design with traditional standard systems.
4. Design using VHDL/microcontroller with simple examples.
5. Explanation of an application case. Resolution of a simple problem, step by step.
6. Classroom practice: resolution of a problem with a slightly higher complexity and solution in the classroom.
7. Laboratory practice: resolution by the students of another problem and practical implementation.

Following a set of sessions comes the explanation in depth of the content seen.

For reinforcing the knowledge given the previous week, for the following session the students have to submit proposed problems, which, after their correction by the teachers, can be used as a support point for the resolution of the telematic test. Both the problems and the test can be evaluated, encouraging the students to work continuously and favouring their learning.

In order to keep the students' attention and relate it to what is of interest to them, participation through questions, problem solving by students who go out to the blackboard, or the specification of the theoretical content taught in examples of real and immediate application to their working future are techniques that have been maintained and enhanced for their multiple benefits [10, 11].

Finally, a final project is mandated to train and evaluate the transversal competence of creativity, innovation and entrepreneurship, with the characteristics of:

1 Gamification: it is a car-alike robot competition.

2 Free-choice development based on clear objectives.

The Hyperloop Pod Competition series alike checklist of requirements included a set of minimal tests that the robot had to pass to get access to the real competition environment. In this way, the students knew clearly what requirements the robot had to meet, on the basis of which they had to build the rest of the code for the different disciplines of the competition, for example:

1 Switching on without movement and flashing LEDs.

2 The robot starts to move after pressing the START button on the control, indicated by the LEDs.

3 The robot stops when the STOP button on the controller is pressed, indicated by the LEDs.

4 Among others...

At the same time that the students were given an initial course, they were given a field of possibilities to try to implement the best strategy (with its consequences in terms of technical development) to win the competition. Some groups devised the implementation of advanced control techniques, a subject that is seen later on the degree, and tried to use them.

The competition took place in the school's hall, open to the public, but the evaluation of each team did not directly take into account the ranking, but another set of evaluable boxes, the clarity and correctness of the code and the short explanatory memory of the implemented functions.

As can be seen in the article describing the methodology [1], year 2018-19 vs. 2017-18 there is an increase on the mean (8.04 vs. 7.37), Q1 (7.61 vs. 6.70), median (7.93 vs. 7.20), Q3 (8.52 vs 8.00), less standard deviation (0.86 vs. 1.33), with standard mean error of 0.19 and 0.25, respectively.

## 5 CONCLUSIONS

The inclusion of PhD students in the elaboration of the teaching methodology has given satisfactory results, outlining different aspects of the learning-teaching process that was being carried out so far in the subject.

Collaboration with recent graduates in improving educational quality offers a perspective closer to that of the students, so that the most difficult or least accepted aspects of the transmission of knowledge and skills by students can be ironed out.

This experience has been enriching for both Full Professors and PhD students and shows another way of working to continue the development of education that contemplates the highest standards.

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