# Methodology Updating Experience in Basic Digital Electronics Teaching

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*Abstract*—**This contribution describes the experience of updating a basic digital electronics course in a Computer Science grade as a consequence of the new grades introduced by the European Higher Education Area (EHEA) in a Spanish university. The group under study is special in because it is taught in English under a pilot scheme carried out by the University of Seville. Besides this singularity, a deep update of the teaching methodology and evaluations has been carried on. In this contribution the authors analyze the results of the new methodology taking into account the academic grades of the students and the opinions of both students and instructors.**

***Keywords.- methodology, EHEA, electronics teaching.***

## I. INTRODUCTION

The adaptation of the Spanish higher education to the new degrees under the European Higher Education Area (EHEA) is a great opportunity to review the contents and methodology of the electronics courses. This review is useful for those courses that are completely new and also for the courses that are basically and adaptation of the old ones found in the previous education plans.

The objective of this contribution is to discuss and document the experience about the adaptation process of a basic digital electronics course of the first year in a Computer Science curriculum. The experience is carried out in one of the course's groups in is based in the results of two semesters in 2010/11 and 2011/12 academic years. This adaptation could have followed a continuist approach since it is a general matter which fundamental content is unchanged, but the authors have opted for introducing deep changes in the way the contents are introduced to the students, the methodology and the evaluation methods. The new methodology is based on the introduction of hardware description languages (HDL) from the start of the basic digital electronics teaching and on the introduction of continuous assessment techniques that avoid the use of exams with accumulated matter.

It is important to emphasize that this contribution does not include any methodology innovation in a general sense since the use of HDL's and continuous assessment techniques are common in higher education. The interest of this contribution is in the innovation introduced at a local level and the conclusions derived from this experience that can be of interest to instructors of similar subjects that face a similar renovation process.

The experience is carried out in a somewhat "special" group that is taught in English when the common language for the rest of the courses is Spanish, under an internationalization project ongoing in the University of Seville (Spain) and the Computer Science School. Teaching one of the groups in English has a dual objective: on one hand, to easy the entrance of foreign students and, on the other hand, to prepare local (Spanish) students to continue their studies in other countries. In the first two years of the course, most of the students are Spanish living in the area of the University, as can be expected from a first semester course. However, the number of foreign students during the second year has been increased with students that were not still familiar with the Spanish language. Other courses given in English during the second semester have a higher number of foreign students since many of the arrive on the second semester. Although the use of an foreign language in the course is a special character of the analyzed group, this contribution focuses more on the methodological renovations than in this special factor.

The analyzed course is entitled "Digital Electronic Circuits" (DEC) and is a basic matter in the three Computer Science degrees taught in the School: Computer Engineering, Software Engineering and Information Technology. The course includes the traditional topics of an introductory digital electronics course: digital devices, digital codification, combinational and sequential circuits (logic level). The RT and system levels are studied in follow-up course of the second semester of the same year. The course covers the same content of the previous plan course entitled "Computer Fundamentals" given in the same year and semester.

The methodology changes introduced, which are detailed in the following section, aim at the following objectives:

- Make the course more attractive to the students.
- Improve the interest of the students on the digital electronic design and computer engineering.

- Improve the self-learning capabilities of the students.
- Complement the theoretical learning with real and practical examples that the students can implement in the laboratory.
- To make a continuous assessment of the students.

In the next section, the traditional and proposed methodologies are analyzed, with the expected outcomes. In Section III some results about the learning process are summarized and analyzed, and conclusions are derived in Section IV.

## II. METHODOLOGY

### A. *Traditional methodology*

With "traditional methodology" we mean the methods and resources used in the precursor subject "Computer Fundamentals" of the previous curriculum. This approach inherits the general characteristics and activities widespread in university education in general, such as a predominance of lectures and a little communication between instructors and students. In the case of the matter at hand, the traditional methodology was characterized by the following:

- Teaching lectures based on both theoretical and practical concepts (problem solving).
- Big collections of exercises available to students, with solutions based on calculations with "pencil and paper."
- Resolution of a selection of the proposed problems by the instructor, in the practical hours available.
- Lab-based assemblies with discrete components: resistors, diodes, MSI devices (7400 family, etc..).

In the authors' experience we can draw several shortcomings of using this traditional methodology. These deficiencies are mainly skills for problem solving and the realization of practical assemblies that the student is able to achieve. These deficiencies are:

- The full resolution of the available exercises is not affordable in the time available, having difficulty selecting an appropriate subset.
- The time available in class to solve problems can cover only a small set of them, so the student does not receive feedback on the rest of the work done.
- Problem solving using only pencil and paper is far from "realistic" current electronic design, which uses computer tools extensively.
- The interaction between instructor and student is poor because of the large number of students per group and an endemic reluctance of students to attend the instructor's office hours, especially in the first year's courses.
- The projects that can be addressed in the laboratory with the use of only discrete components is very limited and falls far short of the problem-solving skills achieved by students in the theoretical and practical classes. For example, a student can design a complete digital clock, but the implementation is not achievable in practical lab sessions using discrete components available for the highly complex mechanical assembly.

Contrary to what it might seem, this contribution is not intended as a critique of this traditional method, since it would be unfair given that overcrowded groups are common in the first year's courses, which has given this teaching configuration in most university degrees. However, the configuration of smaller groups in many of the new degree allows rethinking current teaching organization using methodologies that benefit from this.

### B. *General proposed methodology*

As already mentioned, the group analyzed in this contribution receive teaching in English throughout all courses of the degree. The group is limited to 25 students, although in the two years that this initiative has been going on has not come to fill the quota, with 14 and 21 students enrolled in courses 2010/11 and 2011/12 respectively (students can choose the English group only for some of the courses of the year).

Because there are fewer students per class and consistent it is posible to rethinking the general methodology used coinciding with the introduction of new graduate degrees. The most important aspects of the proposed methodology are:

- The contents have remained virtually the same of typical introductory course in digital electronics.
- Resolution methods using pencil and paper are presented as a useful tool for understanding fundamental concepts, but not as the ultimate tool for solving practical problems.
- The number of proposed exercises has been reduced to a significant set that is given to the student as an assignment to be solved in limited time span.
- Hardware Description Languages (HDL's) are introduced as a formal method of representing the functionality of digital circuits and as a means of access to simulation and automated design of circuits.
- A continuous assessment system has been implemented based on approximately weekly tasks with close monitoring by the instructor.
- The design on programmable devices (FPGA) is introduced in the laboratory.

As could be seen, one of the most important aspects of the proposed methodology is the introduction of HDL's. The suitability of the introduction of this tool in basic subjects of first year is often discussed. In the national picture of Computer Science and similar degrees we can find similar cases where HDL's are introduced from the beginning as those who leave this for higher courses or specialized courses. The main reasons for the introduction of HDL's in this proposal are as follows:

- Using HDL's the student is able to deal with broader problems with the same conceptual complexity.

- The use of HDL's allows the simulation of the proposed designs using test benches. In this way the student has a valuable self-learning tool as it can check for himself whether the proposed solution is correct or not.
- The use of HDL's allows to introduce students to designing simple test benches to understand the importance of digital design testing.
- In the laboratory, the use of HDL's, along with automated synthesis tools and FPGA devices allows us to tackle projects of interest and complexity similar to those seen in theory: calculator, electronic locks, timer, etc., While giving the student a complete view of the design process of modern digital circuits.

While the use of HDL's is a fundamental aspect of the proposed methodology, it is important to clarify that it is not an objective of this methodology to give students a comprehensive training in HDL's design techniques, which is left for more advanced courses. The introduction of HDL's is done gradually, with the structures necessary to describe the digital items that are introduced in each unit and always with reference to the actual circuit.

Among the diversity of existing HDL's, the best options, given the contents of the subject, are Verilog [1] and VHDL [2]. Although both languages are perfectly valid for the stated objectives, we prefer Verilog for its compact syntax and simplicity in data types, which allows to introduce the concepts of the subject without going too deeply into the language itself, such as discussed in the previous paragraph.

### *C. Specific methodology and evaluation*

The proposed methodology distinguishes three types of activities dedicated to evaluate three different aspects: the theoretical understanding, problem-solving skills and ability to implement circuits in the laboratory.

The lectures follow a traditional outline, based on real examples and including techniques for designing digital circuits in a systematic way: functions simplification, Karnaugh maps, state diagrams, etc. However, as mentioned above, the systematic techniques are presented as an example of the importance of automation of the tasks in the digital circuit design and not as a suitable technique for real designs. Automated synthesis from the HDL's is introduced as a practical tool arising from these systematic techniques.

After each theoretical unit, a collection of 4 or 5 problems to be solved by students is proposed to be solved in approximately one week. To solve the problems both pencil and paper and Verilog design techniques are used together with simulation. To solve problems that require descriptions in Verilog, students have a full set of samples prepared by the instructor. Some of the proposed exercises consists on modifications of these examples while others require a complete solution. Within the time available, students are encouraged to consult with the instructor or classmates all doubts that may arise in order to get to solve all the problems within the time limit given. To solve problems using Verilog students are encouraged to use Icarus Verilog simulator [3] and the visualization program GTKWave [4]. These programs are free and very lightweight platform that allows an easy introduction to the simulation of Verilog descriptions without introducing the complexity of complete design environments, which is left for implementation tasks in the laboratory.

Six laboratory sessions are proposed. In the first two sessions the students learn the use of laboratory instruments and electronic circuit assembly with simple combinational logic gates and LSI/MSI components. The remaining sessions are conducted using Verilog and implementation on FPGA using the Xilinx ISE design environment [5] and the Digilent Basys2 development platform [6]. In many cases, the circuit to be implemented in the laboratory has been the object of the proposed assignments, so that students are already familiar with the operation of the circuit design and features, so that the laboratory work focuses on implementation, testings and improvements.

The evaluation distinguishes between three types of activity: theory, problems and laboratory, and is performed as follows:

- Theory: After the end of each unit a 10 questions multiple-choice exam is carried out. The objective of this test is to evaluate the compression by the students of the fundamental concepts of the subject.
- Problems: after the deadline given for the proposed assignments, the student must make a defense of the proposed solution, either in class or during office hours with the instructor. The instructor assesses rather than the solution (which must be correct) as the ability of students to explain and answer variants and alternatives that the instructor proposes. The objective is to evaluate the student's ability to solve problems and possible variants.
- Laboratory evaluates the student's ability to reach an implementation of the proposed circuit in the lab sessions and to implement improvements and changes proposed.

Each type of activity is scored between 0 and 10 points. The final grade depends on attending all lab sessions and having obtained at least a score of 3 on each type of activity. In this case we calculate a weighted final grade where the theory has a 25% problem solving 50% and the labs by 25%.

## III. RESULTS

In order to assess the methodology that is being carried out, this section shows some data on the results obtained during the last two years the course is being imparted, and an analysis thereof. The results include academic results, feedback from students and the instructors' perception over the two years.

### *A. Academic results*

Table I shows the academic performance of the group analyzed (DEC-EN) in the years in 2010/11 and 2011/12, together with those of other groups whose comparison is interesting: the regular groups taught in Spanish in 2010 (DEC-S) and all groups of the precursor Computer Fundamentals course in the last academic year it was held (CF). The results reflect the number of students enrolled, the number of students presented and compared the percentage of those enrolled, the pass rate compared to enrollment (%A / Enr), the pass rate versus presented (%A / Pres) and the percentage of students with grades 7 (from 0 to 10) or higher compared to those presented (%N + / Pres).

First, we note that the percentage of students presented does not vary significantly among different courses, except in the course CF, which the lowest percentage of presented can be explained based on the accumulation of repeaters, a fact that does not occur in other subjects being the first or second year of teaching, so this accumulation has not taken place. Although it is logical that these students have a special motivation to choose a subject that, for most students, it is not taught in their native language, this fact is not reflected in the percentage of students presented, which is similar to groups taught in Spanish.

TABLE I. COMPARISON OF ACADEMIC RESULTS.

| Course | Nº Enr. | Pres.(%) | %A/ Enr. | %A/ Pres. | %N+/ Pres. |
|---|---|---|---|---|---|
| CF 09/10 | 195 | 67(34) | 14 | 51 | 6 |
| DEC-ES 10/11 | 120 | 67(56) | 28 | 49 | 22 |
| DEC-EN 10/11 | 14 | 8(57) | 43 | 75 | 63 |
| DEC-EN 11/12 | 21 | 13(62) | 38 | 62 | 15 |

As for the results themselves, there is a higher pass rate in English class during 2010/11 compared to groups in Spanish and the results of the previous course (CF). These better results are given both for the students enrolled as of the presented and we believe this is significant but not complete since the results of the groups in Spanish for the year 2011/12 are not available yet. It is also significant that the English group results were significantly worse during 2011/12 that during 2010/11, although they remain above the results of the groups in Spanish and CF. This difference is even more remarkable in the percentage of students with high grades, with very good results in this regard during 2010/11 and results on the average in 2011/12.

### *B. Students' opinion*

We believe that in this type of experience it is essential to view students as actors in the teaching-learning process. To obtain this view we has asked the English group students of year 2011/12 to complete a questionnaire designed to assess the student's perception regarding the methodology of the course. Since the evaluation capacity in absolute terms by first year students is limited, the questionnaire focuses primarily on comparison to other courses and qualitative aspects. The questionnaire was completed by 9 of the 21 students enrolled. Considering that the number of students who have made effective monitoring of the course is about 15 and between the 9 are both students who have passed the subject as not (the questionnaire was made before the final grades) we consider that the results are representative. The fact that many students leave the course, even without attending a single class, is a widespread problem in all degrees of the school and, although it's analysis is of great interest, it is beyond the scope of this contribution.

The questionnaire results are shown in Table II. Each student appreciated their level of agreement with each statement from 1 to 5. The statements are written so that 1 is the worst rating and 5 the most favorable. 3 rating and above are considered favorable and below are considered unfavorable. The table shows the average valuation along with the standard deviation.

TABLE II. STUDENT OPINION ON THE METHODOLOGY EMPLOYED IN THE COURSE. RATING: 1-STRONGLY DISAGREE / MUCH WORSE 3-INDIFERENTE/SIMILAR, 5-COMPLETELY AGREE / MUCH BETTER.

| Questions | Mean | Std. Dev. |
|---|---|---|
| 1. English has not been a problem to follow the course. | 4,78 | 0,42 |
| 2. The possibility of studying the subject in English is positive and beneficial for students. | 4,56 | 0,68 |
| 3. Using Verilog to solve problems is useful and relevant to the course. | 3,33 | 0.94 |
| 4. Using Verilog to perform laboratory practice is useful and relevant to the course. | 4,11 | 1,20 |
| 5. The task-based methodology is preferable to partial examinations. | 5,00 | 0,00 |
| 6. Rate the overall interest of the course compared with other courses of the same year. | 3,78 | 0,63 |
| 7. Rate the effort required to follow this course compared with other courses of the same year. | 3,89 | 0,57 |
| 8. If I had to repeat the course again would do it in the English group. | 4,89 | 0,31 |

We note that the assessment is favorable in all the points asked. Students particularly value the opportunity to study the course in English (questions 1 and 2), not having encountered major difficulties because of the language. Although it is clear that students voluntarily chose to study the subject in English, the good results show that they have not been disappointed by their choice.

Another aspect that is particularly well rated by the students is the methodology based on guided tasks rather than exams (question 5), where all the students have graded this statement with the highest score. Using Verilog has also been well appreciated by the students (questions 3 and 4), although more for the laboratory than to solve problems, while the first case depends largely on the second.

Compared with other course of the same year, all students consider the analyzed course of higher interest and easier to follow than other courses. Finally, all students declare, with almost the highest degree, that of having to repeat the subject would do it again in the English group.

### *C. Percepción of instructors*

Finally we give a few details of the teaching-learning process as perceived by instructors of the course. Although difficult to quantify, these details provide valuable information for the enhancement of the methodology implemented.

Regarding the various activities of the course, students obtain the worse grades in the theorical areas. The reason may lie in the relatively low weight of this activity compared to the resolution of problems (25% vs. 50%) and lower student interest by those concepts whose understanding requires some intellectual effort without an immediate practical motivation .

As for the problem-solving activity it is noteworthy that there has been a noticeable difference between the students in 2010/11 and in 2011/12. In the first year, most students that followed the course took advantage of group work and performed the tasks in a comprehensive way and obtained, at the individual level, a high skill in them, which resulted in high-scoring, as shown in Table 1. However, during 2011/12, students have worked more individually or in small groups (two or three at most). Queries to the instructor have been scarce and this has resulted in poor performance of the tasks and worse ratings. In addition, there have been cases in which students working in groups have not been able to demonstrate their skills at the individual level which was not the case in the previous year.

As for laboratory activities, these have been well accepted by students, with the activity likely to have been led to greater motivation. The introduction of Verilog and FPGA design has been instrumental in this aspect since students have been able to implement useful circuits of moderate complexity according to the contents and practical skills developed in the course, as a calculator, an electronic lock or a digital stopwatch. It is noteworthy that most students have demonstrated ability to perform the modifications proposed by the instructor in the designs in Verilog and test these changes by simulation and by actual circuit implementation.

For nearly all of the students, the use of English has not led to any noteworthy additional difficulty for the development of the course. We used some flexibility regarding the language in the sense that, while all group educational activities were conducted in English, the student was free to use Spanish in individual activities such as tutoring or class presentations. We believe this flexibility is important to ensure the participation of students who are perfectly capable of following the class in English but have difficulty expressing themselves in this language.

## IV. Conclusions

From the above data we can draw several interesting conclusions. First, the experience of teaching a course in English even for a majority of Spanish-speaking students is positive, is highly valued by students, which do not find great difficulties because of the language, even though some of them have virtually no skills to speak English.

In addition, academic results of the analyzed group are significantly higher than those obtained in other groups of the subject and those obtained in the precursor course of the curriculum. We believe that this improved performance is due to the methodological changes since they are supported by the student's opinion, who see how they can get pass the course with less effort.

In our opinion, in obtaining these results play an important role introducing Verilog as a tool for problem solving and implementation of circuits in the laboratory, something that is especially appreciated by students.

Although the overall results are satisfactory, it is necessary to collect more information in later years and seek improvements in the proposed methodology. In this sense, some of the improvements that are being evaluated for future years are as follows:

- Promote teamwork and consultation to instructors to solve the proposed tasks.
- Improve the presentation of the units by using practical examples thar are going to be implemented at the end of the topic.
- Perform a more personalized evaluation of the problem solving activities.
- Incorporation of open labs where the student has free access to laboratories for extended hours so that they can go deeper into the practical work and to tackle more ambitious projects.

## Acknowledgment

This work has been partially supported by the Ministerio de Ciencia e Innovación of the Spanish Government under project TEC2011-27936 (HIPERSYS) and by the European Regional Development Found (ERDF).

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