Analysis of the results of four years of research and application of a student-centered system based on the ECTS to first-year students in order to improve their performance in the subject AC-I

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***Abstract*—In this paper, the results of four years of a research aimed at carrying out a comparative analysis between the application of the European Credit Transfer and Accumulation System (ECTS) and the traditional teaching and learning system (TTLS) to first-year students, in order to improve their performance in the subject Analysis of Circuits I (AC-I) are presented. The ECTS is a student-centered system based on the student workload required to achieve the objectives of a program, and the outcomes of its application have been quite positive. In order to conduct the statistical analysis of the data collected in the educational experiment and make the right decisions, at the beginning of the experiment, during the first years, both treatment and control groups were formed and several tests of hypothesis were conducted in the groups that participated in the educational experiment. Neither all the students who took the above-mentioned subjects nor all the professors who taught them participated in the experiment. However, during the last year of the experiment all the students and almost all professors participated in the experiment. Since the beginning of the experiment, satisfactory partial results have been gradually achieved, and when we managed to involve all the students and almost all professors in the last year of the experiment, the overall results where not only satisfactory but also significantly better than the ones achieved in the previous years. The students satisfaction and confidence have increased gradually, and, in general, the students under the ECTS passed more exams and with better Grades than the students under the TTLS. Also, the teaching-learning methodology strategies, tutor sessions, assessment methods, use of the virtual learning environment (VLE), student teamwork, and collaborative work among professors performed better under the ECTS than under the TTLS.**

***Index Terms*—student-centered learning system, first-year students, statistical analysis**

I. Introduction

In this paper the results of four years of research and application of a student-centered learning system (SCLS) to improve the performance of first-year students (FYS) in the subject AC-I are presented. The above-mentioned SCLS is based on the application of the ECTS [1] to the EUIT de Telecomunicación (EUITT) at the Universidad Politécnica de Madrid (UPM), and was born five years ago as a result of the adaptation of the first-year course of the EUITT-UPM to the European Higher Education Area [2].

Since the academic year 2005-2006 in the EUITT-UPM the higher education system has experienced a positive change from the traditional teaching and learning system (TTLS), which has failed to motivate students for further learning and does not take into consideration their needs and perceptions, to novel systems based on the student workload required to achieve the objectives of programs.

While in the TTLS credits are given only for student workload in class, without taking into consideration the independent and private study, and the preparation of projects and examinations either, in the SCLS mentioned in this paper credits can only be obtained after successful completion of the work required and appropriate assessment of the learning outcomes achieved.

The learning outcomes are sets of competences, expressing what the student will know, understand or be able to do after completion of a process of learning [1].

In the EUITT-UPM, both the TTLS and the SCLS consisted of 15 teaching weeks, and the subject AC-I had allocated 7.5 non-ECTS credits for the TTLS and 7.14 ECTS credits for the SCLS [3].

1 non-ECTS credit stands for 10 working hours of the students in lectures, seminars and laboratory sessions, without taking into consideration the student workload after classes, the independent and private study, and examinations.

1 ECTS credit stands for around 25 to 30 working hours and, as mentioned in previous sections, credits in ECTS can only be obtained after successful completion of the work required and appropriate assessment of the learning outcomes achieved.

Thus, due to the fact that the current emphasis is on under-

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standing and measuring students' learning, rather than teaching [4], the content-centered approach [5] is soon-to-be obsolete and the current higher education system is moving on to the student-centered approach [5]. In the latter, developing the cognitive abilities of the students is of paramount importance rather than teaching, and it also applies collaborative and cooperative learning methodologies efficiently [6], [7], [8].

The subject AC-I is a fundamental one and it is taught in the first semester of the first-year course in the EUITT-UPM. Also, the students that take this subject can be either new first-year students or students who are taking the subject again. Several educational experiments have been conducted in order to improve the performance of the students in AC-I, and their results have shown that when the academic results of one year are compared with the ones of another year the differences between both are not always significant. Therefore, professors have to keep themselves improving the teaching and learning system continuously.

In this paper the problem of analysis of the results of the educational experiment is formulated as a statistical analysis problem and some decisions about the efficiency of the proposed SCLS on the basis of sample information are made.

II. General description of the educational experiment that have been conducted in the last four years

A. First two stages of the experiment: All first-year subjects

The beginning of the educational experiment dates back to the academic year 2005-2006. In that stage of the research the coordination among the 14 professors that decided to participate voluntarily in it was the key issue. There were professors from different departments and from all the subjects that are taught in the first academic year of the EUITT-UPM [3], AC-I was one of the subjects under study.

Generally speaking, the research group had several regular meetings during the whole academic year and, after each meeting of the research group, several important decisions regarding the curriculum development and the application of the ECTS to the EUITT-UPM were made. Such decisions were focussed on the following issues:

1) Determining the student workload and its translation to ECTS.
2) Developing new educational methods that guarantee the perfect harmony among all the subjects.
3) Promoting tutor session.
4) Applying the same evaluation methods in all the subjects.
5) Setting the standards of using the Virtual Learning Environment (VLE).
6) Strengthening the cooperation among all the subjects taught during the academic year.

Also, during the academic year 2005-2006 32 new first-year students (FYS) were chosen to participate in this educational experience. These students were chosen at random from a group of 150 new FYS that wanted to participate voluntarily in the educational experiment. Those students had both a lecture room designed to facilitate teamwork (with Wi-Fi technology, laptop computers, a slide projector and adjustable desks aimed at making the students feel comfortable in the classroom), and a laboratory room consisting of 16 student workbenches equipped with the conventional laboratory instrumentation that can be found in an electronic engineer's workbench [9].

At that time, it was decided to design each semester taking into consideration that the student workload is 800 hours and that during the examination weeks the students devote 20 hours to study each particular subject to successfully pass the final exams. The marking scheme for each subject was constructed as follows: 70 % exam paper and 30 % continuous assessment, including participation in classes and activities developed in the VLE; and for the VLE the software system used Moodle.

Furthermore, the VLE was used to provide follow-up materials online, continuous assessment tasks for their (online) discussion, homework assignments, and online activities or exercises. Also, it was used to make available the material from the professors and the scheduling of each unit of work, to participate in forums assigned by the professors, and to provide forum questions and e-mentoring or e-tutoring.

During the second stage of the educational experiment, the academic year 2006-2007, the working methodology was the same as the one of the first year, the number of new FYS that participated in the experiment was 90 and the number of professors was 17. In addition, the new FYS that participated in the educational experiment were not asked whether they wanted to participate voluntarily in the experiment. But they were all informed about the project when they came to the school to enrol in the academic year 2006-2007, and at that time the professors let the students know that some of them were going to be chosen at random to participate in the project.

Generally speaking, during the first two stages of the educational experiment, which focussed on all the first-year subjects, the overall opinion of both students and professors was quite positive. The two things that they both valued the most were the continuous assessment and the use of the VLE as a support to both the developing of student learning skills and the collaboration and cooperation among students.

On the other hand, as at university professors have also to do research on other fields such as Telecommunication Engineering, Electronics, Physics, Mathematics and so on, the general opinion of them was that the pass from the traditional teaching and learning methodology to the new one had caused an increased in their workload, at least in the first two stages of the educational research project. Also, in spite of the fact that most of the students who participated in the project were in favor of the new methodology, some of them thought that the workload was higher [10], [11].

Therefore, in order to make the system more efficient and to find one that works best for both professors and students, some decisions were made during the third stage of the experiment, the academic year 2007-2008. For instance, that academic year faculty and student mentors were introduced, and all the lecture rooms of the school for first-year students were

designed to facilitate teamwork among students and to make them feel comfortable in classes.

Moreover, in that academic year there were two kind of groups of students, one consisting of new FYS and the other consisting of students who were taking the subjects again. Also, in the academic year 2007-2008 the marking scheme depended more on continuous assessment tasks (i.e., partial exams, tests, projects, homework assignments, and so on) than on the final exam paper. In fact, in AC-I outstanding students did not have to do the final exam paper, they passed the subject if their performance in the continuous assessment tasks was very good.

In order to round-up the first two stages, it can be said that there were weaknesses such as the high student and professor workload, and threats such as the lack of communication among the professors that participated in the project and the ones that did not participate in it, some professors were not 100% willing to change from the TTLS to the SCLS based on the ECTS, some professors did not consider research in Engineering Education as scientific research, and in order to improve communication, teamwork and lateral thinking, the amount of interdisciplinary lessons had to be increased.

However, on the other hand, there were also strengths such as the overall improvement of the student performance in all the subjects, the blended approach to teaching, face-to-face and e-learning, the use of interactive methods to break the monotony, the use of the VLE, the good coordination and cooperation among all the professors subjects that are participating in the project, and so on; and there were many opportunities as well, in its first two stages the educational experiment allowed us to enjoy the benefits of the new teaching and learning methodology, and to be prepared for collaboration and cooperation in excellence in engineering education with other member states of the European Community.

Taking into consideration both the positive aspects and the things that the research group had to improve from the first two years of the educational experience, it was decided to continue the research focusing only on each specific subject, instead of focusing on all the first-year subjects at the same time.

To that end, the resources were optimized and the research group tried to involve more professors of each specific subject in the experiment, which in contrast to the first two years of the experiment in the case of AC-I it has been a success since the academic year 2007-2008. Currently, all the professors who teach that subject have gotten involved in the experiment.

The next third and fourth stages of the educational experiment that will be described next (i.e., academic years 2007-2008 and 2008-2009), will be devoted specifically to describe the part of the experiment focused only on the subject AC-I.

B. Last two stages of the experiment: AC-I

During the third stage of the educational experiment, the academic year 2007-2008, the working methodology was the same as the one of the first two years and, as mentioned above, some decisions were made to make the system more efficient and better adapted to the needs of both students and professors. In this stage of the experiment 222 students who had to take the subject AC-I were chosen to participate in the experiment. Those students were chosen at random from the group of 444 students that were enrolled in AC-I in the first semester of the academic year 2007-2008 [12].

Also, those 222 students were divided into 4 groups of students with the following characteristics:

1) Group A: 50 new FYS. These students studied under the TTLS.
2) Group B: 47 new FYS. These students studied under the SCLS.
3) Group C: 64 students who were taking the subject again. These students studied under the SCLS.
4) Group D: 61 students who were taking the subject again. These students studied under the TTLS.

In addition, the number of professors of AC-I who participated voluntarily in the experiment was 4. Two of them had good experience with the application of the student-centered approach to improve the performance of students, and the other two professors had good experience with the application of the TTLS.

Furthermore, for the TTLS the marking scheme for AC-I was constructed as follows: 75% the final exam paper, which is done by the students in one specific day during the examination weeks, after having finished the 15 teaching weeks of the semester, and 25% the laboratory exam in the last week of the semester.

Taking into consideration the results of the two previous academic years, in the third stage of the experiment for the SCLS it was decided to construct the marking scheme based on continuous assessment tasks as follows: two exam papers, 30% the first exam paper (in the middle of the semester) and 37.5% the second exam paper (in the last week of the semester); 7.5% ten 30-minute knowledge tests given to the students during all the semester (two 10-questions knowledge tests given at the end of each one of the five units of work of AC-I), this activity was carried out using the VLE and the tests were made by using the platform Moodle; and 25% continuous assessment activities in the laboratory including a final laboratory exam in the last week of the semester.

Also, the professors who participated in the educational experiment prepared the knowledge tests in Moodle in such a way that none of the tests that the 222 students had to do had the same 10 questions. The questions were chosen at random by Moodle.

The 10 knowledge tests (i.e., 2 tests for each unit of work) that were given during all the semester were mandatory for the students of the Groups B and C. However, these tests were optional for the students of Groups A and D.

An example of the full version of one of the above-mentioned 10-questions knowledge tests can be found in the Appendix of [12].

Finally, during the academic year 2008-2009, the last stage of the experiment, all the FYS (i.e., new FYS and students who were taking the subject again) participated in the experiment

and the number of professors who taught the subject AC-I that participated in the experiment was 7.

Moreover, from that academic year on the marking scheme was the same for all the students: 3.75% ten 30-minute knowledge tests given to the students during all the semester, those tests had the same characteristics as the ones of the academic year 2007-2008; 15% the partial exam paper (there was only one) in the middle of the semester; 56.25% the final exam paper; and 25% the laboratory exam in the last week of the semester.

As will be shown in the next section, the academic results of that year were the best, both professors and students were very happy with them and in many aspects all the effort of many years of the educational experiment started to pay back.

III. Statistical analysis of the general academic results of the students during the experiment

In order to conduct a comparative analysis between the general academic results of all the FYS right before the beginning of the experiment and the ones during the last four years of it, a comparison of the final Grades in the subject AC-I among the years 2004, 2005, 2006, 2007, 2008 and 2009 was carried out in order to say, on the basis of the evidence obtained, whether the observed differences were significant and either accept or reject the hypothesis that the students under the SCLS based on the ECTS performed better than under the TTLS.

At this point, it is important to point out that the years 2004 and 2005 are important because they were the last two years in which there was no research in engineering education in the above subject. From those years on the research started with a small group of FYS students and only 2 professors of AC-I, and at present (in the academic year 2009-2010) all the FYS and all the professors who teach AC-I are involved in it, which has been a significant step forward in the educational experiment.

The first step of this section was to conduct an exploratory examination of the data. To that end, the R system for statistical computing was used [13], the data set was loaded and the variables (Grades2004, Grades2005, Grades2006, Grades2007, Grades2008, Grades2009) accessed.

Figure 1 shows the Box-plot of the data and Table I shows some summary statistics.

Figure 2 shows the histogram and density estimate of the Grades of the years (2004, 2005, 2006, 2007, 2008 and 2009) [14]. From that figure it can be seen that the distributions are strongly skewed.

The model

$$y_{ij} = \mu_i + e_{ij} \quad i = 1, \ldots, 6 \quad j = 1, \ldots, n_i \qquad (1)$$

is considered. Here, $\mu_i, \quad i = 1, \ldots, 6$, are the mean value of the final Grades of the students, e_{ij} are random errors that follow a normal distribution with zero mean value and standard deviation σ, and $n_i, \ i = 1, \ldots, 6$, is the length of the each variable.

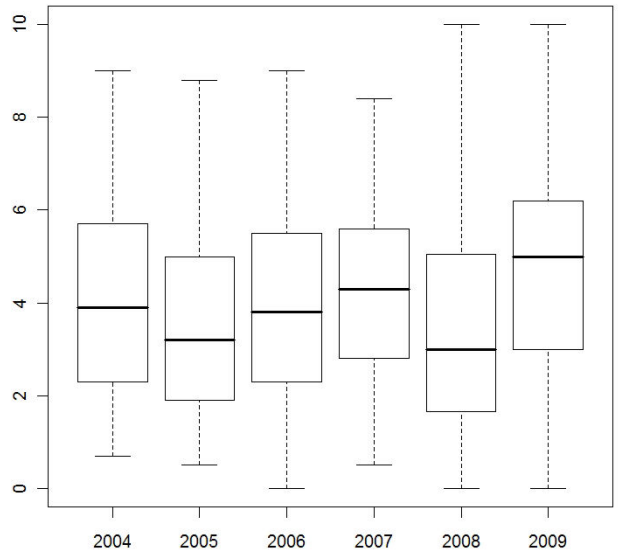

Fig. 1. Boxplot of data

Next, an F test [15] was carried out to see if the means of the Grades were equals.

The hypothesis is

$$H_0 : \mu_1 = \mu_2 = \ldots = \mu_6$$

against

$$H_1 : \mu_i \neq \mu_j \quad \text{for at least one pair } i, j,$$

$$\forall \ \ i, j \in \{1, \ldots, 6\}$$

at level 0.05.

Then, the residuals were used to check the adequacy of the fitted model using a normal Q-Q Plot (see Figure 3) and a normality test statistic (see Table II).

Therefore, the model (1) is considered when random errors do not follow a normal distribution.

Now, the problem may be solved by a rank test such as Kruskal-Wallis [16], [17]. In that sense, Table III was obtained.

Then as shown by the p-value of the KrusKal-Wallis test, H_0 had to be rejected. Therefore, the statistical analysis continued with the study of the academic years in which it can be said that there were significant differences. In short, the experimental groups that led to the rejection of the null hypothesis were investigated. Such an investigation was carried out by using a post-hoc comparison test [18].

To that end, a pairwise permutation test we applied to all possible pairs of groups and as a result, for the data under analysis, it was found that there were significant differences among the final Grades of the students. This information is shown in Table IV.

TABLE I
SUMMARY STATISTICS

	Grades2004	Grades2005	Grades2006	Grades2007	Grades2008	Grades2009
Min	0.700	0.500	0.000	0.500	0.000	0.000
1st.Qu	2.300	1.900	2.300	2.800	1.675	3.025
Median	3.900	3.200	3.800	4.300	3.000	5.000
Mean	4.112	3.437	3.991	4.257	3.517	4.685
3rd.Qu	5.700	5.000	5.500	5.575	5.025	6.200
Max	9.000	8.800	9.000	8.400	10.000	10.000
sd	1.996	1.788	2.028	1.892	2.204	2.184

TABLE II
SHAPIRO-WILK NORMALITY TEST

Shapiro-Wilk normality test
data: residuals
W = 0.9773, p-value $<$ 2.2e-16

TABLE III
KRUSKAL-WALLIS TEST

Kruskal-Wallis rank sum test
data: Teleco and year
Kruskal-Wallis chi-squared = 77.6375, df = 5
p-value = 2.617e-15

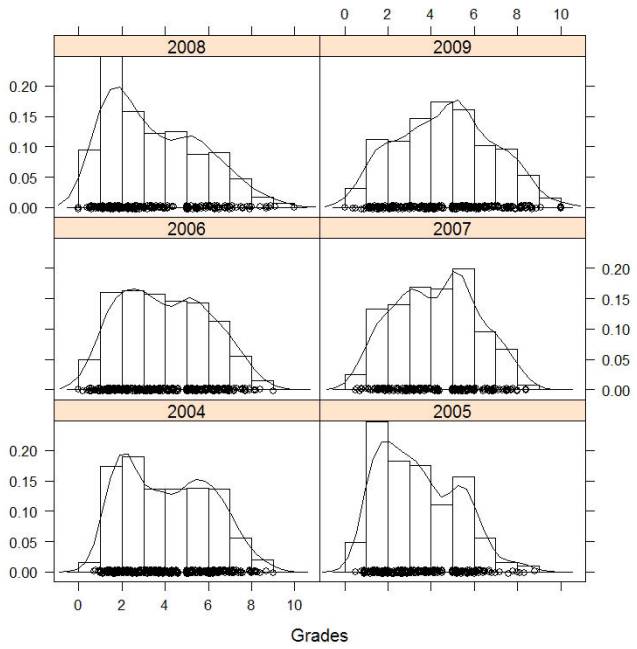

Fig. 2. Histogram and density estimate of variables

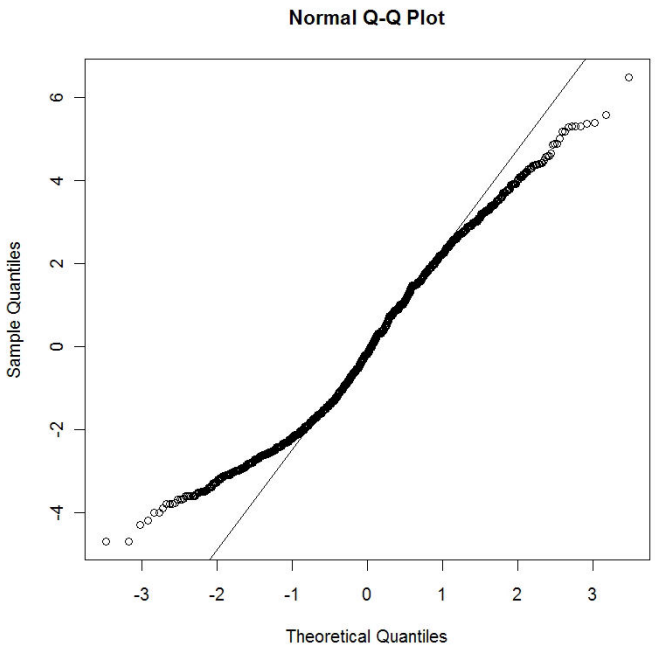

Fig. 3. Normal Q-Q plot

In Table IV, the partial p-values are highlighted with the usual R convention [13]:

Signif. codes: 0 `***´ 0.001 `**´ 0.01 `*´ 0.05 ` .´ 0.1 ` ´ 1

Also, in Table IV `***´ stands for that the observed differences between the specific years under analysis were highly significant, `**´ stands for that the observed differences between the specific years under analysis were very significant, `*´ stands for that the observed differences between the specific years under analysis were significant, and ` ´ stands for that, on the basis of the evidence obtained, the observed differences between the specific years under analysis were not significant.

Table IV shows that the best year was the year 2009, the two second best years were 2004, 2006 and 2007, and the worst years were the years 2005 and 2008.

The general results of the year 2005 motivated the application of the SCLS based on the ECTS to improve the performance of the students and the general results of the year 2008 motivated a change of philosophy.

TABLE IV
PAIRWISE COMPARISON TABLE

	Diff	Partial p.value	
2004-2005	0.67446635	0.000999001	***
2004-2006	0.12052494	0.419580420	
2004-2007	-0.14480756	0.351648352	
2004-2008	0.59491212	0.001998002	**
2004-2009	-0.57359972	0.000999001	***
2005-2006	-0.55394141	0.000999001	***
2005-2007	-0.81927391	0.000999001	***
2005-2008	-0.07955423	0.624375624	
2005-2009	-1.24806606	0.000999001	***
2006-2007	-0.26533250	0.128871129	
2006-2008	0.47438718	0.001998002	**
2006-2009	-0.69412466	0.000999001	***
2007-2008	0.73971968	0.000999001	***
2007-2009	-0.42879216	0.015984016	*
2008-2009	-1.16851183	0.000999001	***

Such a change was necessary because in spite of the fact that the new FYS that were taught under the SCLS in the academic year 2007-2008 had significatively better performance in AC-I than the ones that were taught under the TTLS [12], and that the performance of the students who were taking the subject again that were taught under the SCLS was slightly better the ones that were taking the subject again and were taught under the TTLS, not all the students and professors were involved in the educational experience.

Therefore, taking into consideration both the positive aspects and the things that had to be improved from the academic year 2007-2008 [12], in the academic year 2008-2009 the research group focused its efforts on improving the collaborative and cooperative work among professors and among students as well, on improving the common teaching and learning methodologies, and on trying to involve everyone who was related with the subject AC-I in the experiment. Section II-B was devoted to give a general explanation of what the research group has done since the academic years 2007-2008 and 2008-2009 in order to improve the performance of the students in AC-I.

IV. CONCLUSION

The statistical analysis presented this paper has shown that the application of the SCLS based on the ECTS to improve the performance of FYS in the subject AC-I has yielded satisfactory results. In spite of the fact that there were years in which there was not a significant improvement in the performance of the students and others in which the improvement was slightly better than others, there were years in which there were highly significant differences. The best year was 2009 and the worst were 2005 and 2008.

The results of the year 2005 motivated the application of the SCLS and the results of the year 2008 motivated a significant improvement in the way the SCLS had been applied. Such improvements allowed the professors of the subject to obtain in the year 2009 the best performance of the students in AC-I in the last 10 years.

The overall satisfaction of the students and the professors that participated in this educational experiment was quite positive. Their level of satisfaction was high and their reactions to the improvements in the SCLS were quite positives.

With the SCLS based on the ECTS students have to work harder than with the TTLS but they learn more, pass the subjects with better marks and develop skills that will help them to become good professionals.

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