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Experimental evaluation of the impact of b-learning methodologies on engineering students in Spain

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ABSTRACT

The aim of this article is to highlight the importance of an active learning methodology in engineering degrees in Spain. We present the outcomes of an experimental study carried out during the academic years 2007/2008 and 2008/2009 with engineering students at the University of Salamanca (Spain). In the present research, as we have done in previous ones, we have selected a subject which is common to the four degrees under consideration: Computer Science. This study explores in greater depth the validity of experimental designs coming from educational research and the impact of innovative teaching methodologies. The hypothesis that impulses this research is formulated to ascertain that the learning level and the satisfaction of students will be higher after the implementation of new teaching methodologies (based on constructive learning, collaborative work, and blended learning resources), than in more traditional teaching contexts. The obtained results partially confirm this hypothesis. The ultimate purpose of this work is that of providing evidence that contributes to the improvement of education and teaching methods for a better performance of students in engineering.

1. Introduction

The present research is inscribed in the framework of research, innovation and university teaching, and, more specifically, in the teaching of engineering. The modernization of Higher Education in Europe demands the assessment of new competencies in students, what entails relevant changes in competence design, applied teaching methodology and assessment tools (Escudero, 2010; Huber, 2008; De Miguel, 2006; Olmos & Rodríguez, 2010; Pallisera, Fullana, Planas, & Del Valle, 2010; Redecker et al., 2011; Salaburu, Haug, & Mora, 2011; Villa, 2008; Zabalza, 2007).

Scientific works are being developed in the framework of engineering to produce fruitful results published and presented in doctoral theses, articles and conferences which focus on this area. Some examples of relevant magazines in the field are: Computers and Education (http://www.journals.elsevier.com/computers-and-education/), Journal of Engineering Education (http://www.jee.org/), International Journal of Engineering Education (IJEE) (http://www.ijee.ie./) or European Journal of Engineering Education (EJEE) (http://www.sefi.be/?page_id=20). Some instances of doctoral theses and reports that can be mentioned are: (Bernabeu, 2009; González, Rodríguez-Conde, & Olmos, 2006; Montero, 2008; Tovar, 2006) while some conferences and seminars would be the International Symposium on Computers in Education (SIIE – Aveiro (Portugal), 2011), Frontiers in Education Conference (FIE – Rapid City, South Dakota (USA)), the XIX Congreso Universitario de Innovación Educativa en las Enseñanzas Técnicas (CUIEET – Barcelona (Spain), 2011).

We are dealing with an updated topic where educational research studies are necessary to determine the impact of the educative reform on university students' learning results. With the development of this research we tackle several very relevant aspects in this context: (i) The study of the characteristics that a teaching methodology adapted to the requirements of the European Higher Education Area (EHEA) in the subjects of engineering degrees in Spain should display. (ii) The design and implementation of an adequate teaching methodology that establishes a reasonable compromise between desired characteristics and available resources and (iii) the proposal of new assessment tools adapted to the new methodologies and necessities of the EHEA.

This methodological renewal, that we aim to validate in a scientific way, is going to be supported by the use of new technologies (Barberà, Mauri, & Onrubia, 2008; Cabero, 2007; Gros, 2008; Prendes et al., 2010). On the other hand, computing tools on their own will not automatically change teaching methodologies. This is the reason

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Table 1
Content objectives in the subjects, methodological objectives in the experimental groups.

Content objectives	Methodology objectives
Learn the bases of computer systems from the point of view of both hardware and software	Active learning
Learn how a computer functions, with particular emphasis on the systems of numeration and data encoding	Enhance continuous work: acquire studying habits, sense of responsibility, etc
Be able to identify the elements which constitute the machine and those related to their interconnection through computer networks and the Internet	Promote team-work: development of the capacity for coordination, cooperation, task planning, oral skills, etc
Learn to use a calculus sheet to solve mathematical or physics problems (computing or applied computing)	Favor the development of critical capacity: stimulate the critical approach of the student towards the tasks performed both by the teacher and by his classmates
Learn to use the operating system GNU-Linux (computing systems)	Motivate learning: generate enthusiasm for the subject, sense of learning, of rewarded effort, feeling of self-efficiency

why we are working on blended-learning models (b-learning) (Aguado, Arranz, Valera, & Marín, 2011; Bartolomé, 2004; Dalsgaard & Godsk, 2007; García-Peñalvo et al, 2011; Garrison & Vaughan, 2007; Littlejohn & Pegler, 2007; Llamas et al., 2009); that is to say, a combination of classes to attend and online activities through institutional grids or open-coded platforms and Web 2.0 applications of an individual or group use of both students and teachers.

For the present study we selected as instructional design model the one proposed by Anderson's ACT (Adaptive Control of Thought) cognitive theory (Anderson, 1983). In this theory, the process of learning takes place in three phases, similarly to how a computer works. Firstly, the student acquires a declarative knowledge on a behavior or ability. Then, he or she stores and integrates this information with the procedural knowledge or the knowledge on behavior execution; therefore, there is a transition from knowing «what» to do to knowing «how» to do it. Finally, behavior execution is automatized; that is, the learner requires less memory and conscious processing for the execution, being then capable of paying attention to other demands of stimuli.

From the perspective of a quantitative educational research methodology, we chose a quasi-experimental design with a non-equivalent control group and measures before and after the intervention (Green, Camilli, & Elmore, 2006). In the context of Higher Education, where students are already grouped around subjects within each one of the degrees, the level of control over the assignment of the intervention is usually low. This type of research in natural contexts aims to maintain the internal validity of the study by means of different strategies (control of extraneous variables, pre-/post-test measures, etc.). We subsequently introduce an instance of research under these methodological assumptions.

2. Material and method

The context where this research has been carried out is the Polytechnic School of Zamora, University of Salamanca (Spain). The sample of this study is formed by students enrolled in the subjects Computer Science, Applied Computer Science or Computing Systems during the academic years 2007–2008 ($n = 99$) and 2008–2009 ($n = 101$).

These subjects have six LRU credits,[1] taught in those degrees not adapted to the EHEA, and which are compulsory in the first year of those engineering degrees of the Polytechnic School of Zamora (University of Salamanca). The objectives of these subjects are displayed in Table 1, in accordance with the competencies assigned to them in the new syllabus adapted to the EHES, where they have been allocated six ECTS, and presented in Table 2.

2.1. Objectives and hypotheses

With this research we aim to demonstrate how efficient a new methodology would be in the area of Computing Sciences for Engineering, and we try to contribute to the increase in the level of competence learning of students, and therefore, to the improvement of teaching quality in engineering in the educative Spanish system.

From this departure point, the scientific **hypotheses** that we try to test are:

- Competence learning level of students after the inclusion of new teaching methodologies (based on constructive learning, collaborative work and blended learning resources) will be higher than in traditional teaching contexts.
- Satisfaction level of students towards the new methodology used will be significantly higher than in those students present in a traditional teaching environment.

2.2. Research design

The research methodology that better suits the securing of the objectives planned and provides an answer for the hypotheses formulated corresponds to the quasi-experimental method (control and handling of variables). Experimental techniques have allowed us to test hypotheses through the assignation of different assessment types to different groups of students belonging to different engineering degrees. To choose experimental groups of subjects, to select experimental and control variables and to organize the answers to be analyzed is what we aim to attain with this project. As it has been done in some other studies, we have decided to design a pre-test/post-test with a control group, (Shadish & Luellen, 2006).

2.3. Sample

We can define the sample object of study as the group of students of the Polytechnic School of Zamora, University of Salamanca, in the academic year 2007–2008 and year 2008–2009 (Table 3). In relation to the sample, we will select the subject Computer Science, in the first year of the degree, to develop the experiment. Three will be experimental groups, and two groups will control the rest.

Conditions required in this type of research (personal and contextual variable control, intervention on both students and teachers, voluntary participation of subjects, material conditions of the research, shortage of resources, etc.) have impelled us to privilege internal validity of the study over the external one.

2.4. Variables

Variables considered are detailed below. The independent variable is defined as the 'didactic methodology' used, which is measured in two levels: (a) active learning methodology, with the support of an experimental use of ICTs, and (b) traditional-control methodology. Regarding the principal dependent variable, we

[1] Each LRU credit is equivalent to 10 h of teaching.

Table 2
Competencies assigned to computing systems in the syllabus of the degree in computer engineering and information systems.

Specific competencies	Cross-curricular competencies
Basic knowledge on the use and programming of computers, operating systems, databases and computer programs with applications in engineering	Capacity to organize, manage and plan work
	Capacity to analyze, criticize and synthetize
	Capacity to relate and manage different information and to integrate knowledge and ideas
	Capacity to make decisions
	Capacity for the oral and written communication of knowledge, ideas, procedures and results in their native language
	Capacity to integrate in monodisciplinary or multidisciplinary work groups
	Autonomous learning

Table 3
Groups of students.

First-year groups of computing	Students number 2007–2008 2008–2009	Assignation	*Pre-test* (October 2007) (October 2008)	Implementation (October–December 2007) (October–December 2008)	Post-test (January 2008) (January 2009)
A1 – ITIG* – Experimental Year 2007–2008 and 2008–2009	25	Not random	O_1	Innovation	O_2
	25	Not random	O_1	Innovation	O_2
A2 – ITIM* – Experimental Year 2007–2008 and 2008–2009	20	Not random	O_1	Innovation	O_2
	20	Not random	O_1	Innovation	O_2
A3 – ITOP*-Experimental Year 2007–2008 and 2008–2009	20	Not random	O_1	Innovation	O_2
	20	Not random	O_1	Innovation	O_2
B1 – ITIM* – Control Year 2007–2008 and 2008–2009	20	Not random	O_1	Traditional	O_2
	20	Not random	O_1	Traditional	O_2
B2 – AT* – Control Year 2007–2008 and 2008–2009	75	Not random	O_1	Traditional	O_2
	75	Not random	O_1	Traditional	O_2

* ITIG - Technical Computer Management Engineering; ITIM - Technical Industrial Mechanical Engineering; ITOP - Technical Public Works Engineering; AT - Technical Architecture.

highlight the level of 'competence learning' acquired by students at the end of the semester. As measurement criterion of this variable we took into account the final grade obtained in the subject. As control variables we consider, on the one hand, the level of previous knowledge of students, their marks, learning styles, time devoted to studying, attitudes towards the use of ICTs, and interest towards the content. On the other hand, we took into account that the teacher of all experimental groups is the same, and the planning of the subject is also common.

With regard to the independent variable we subsequently present the didactic methodology employed in this study, both experimental and control (traditional).

2.4.1. Independent variable: traditional vs. experimental didactic methodology

The aim of this research has been to analyze the efficacy of a *blended-learning* (*experimental methodology*) instruction programme specifically designed for the development of the competencies stated in Tables 1 and 2. In order to do so, as has been asserted, we employed as instructional design model the one proposed by Anderson's ACT (Adaptive Control of Thought) cognitive theory (Anderson, 1983): (1) Students acquire a declarative knowledge on the behavior or ability; (2) They store and integrate this information with procedural knowledge or knowledge on behavior execution; therefore, they move from knowing "what" to do, to

Table 4
Task *Let's learn more.*

Units	Task "Let's learn more"
Let us learn more 1	Which of our characters is an expert in the genealogy of European monarchy and participated in the Manhattan project?
	Who proved that Boole's algebra could be represented by electronic circuits and be used to represent complex logic operations? When? (it is not one of our four characters)
	What was Enigma and how does it relate to one of our characters?
	Which of our characters has a moon crater named after him or her?
	Who are John Prespereckert and John W. Mauchly?
Let us learn more 2	Which microcomputer first incorporated an Intel 8080 processor?
	When? Which was the initial logo of Apple computers?
	Who commercialized the first kind of floppy disks for PCs? When?
	Which were the first music CDs that appeared in the market?
	How was the initial size and capacity of the first CDs in the market agreed on? There are several theories
Let us learn more 3	When did the creator of the World Wide Web found the World Wide Web Consortium? Specify who he is and where the www appeared
	Which was the browser on which Internet Explorer 1.0 was based?
	What was TAT-8?
	Who created the first videogame in history? When? Which one was it?

"how" to do it; and (3) Behavior execution becomes automatized, that is, learners require less memory and conscious processing for execution, hence being able to pay attention to other demands or stimuli.

In the present case we have therefore applied this theory to the teaching of the subject of "computing" in engineering degrees.

In order for the student to acquire the demanded knowledge, in a first phase a methodology based on lectures is employed. Classes open with a summary of the contents which we aim to convey, as well as a brief comment on the concepts already presented in previous classes and which serve as link with those we aim to achieve. The class develops with all the audiovisual media, texts, slides, Internet connections, or physical components (hardware) required as support for the explanations and which allow an appropriate level of motivation and interest on behalf of the students. We wish to motive our students to intervene at any time during the classes, to make them more dynamic and to assist their learning. It is important to try to finish the exposition with the most relevant conclusions of the topic that has been dealt with. To enhance students' participation in learning, every 2 or 3 weeks (during the first weeks of class) a series of questions, mainly related to the history of computing (Table 4), were formulated for the students to answer them on the online platform. In the same line, a series of objective self-assessment tests on the contents of the class (formative assessment) were proposed. All the tasks were uploaded on an online course designed in the Learning Management System Moodle in the University of Salamanca.

In a second stage, group tasks were suggested, which we will term complementary work. These assignments include a clearly defined performance guide and a rigorous time planning. We considered that they would facilitate the required learning to cope in the business world, providing not only technical abilities, but also social ones, such as organization, leadership, communication, coordination, tolerance, oral communication, responsibility, and capacity to debate, etc. We aimed to promote the idea of "knowing to do with others".

From our point of view, these team-work tasks constitute an essential tool to achieve a change with relation to the students' mentality concerning the learning process and to modify the classic tendency at University based on a "*passive*" kind of student. It is vital that the attitude to be promoted would be that of an "active" student, who decides his or her own learning process (leading to the third phase, automation).

The planned assignments were the following:

- *Documentation assignment* (type 1), management of bibliographic databases. Managing of databases of research electronic journals to locate articles on a suggested topic. Electronic format.
- *Exercises on numeration systems and information encoding* (type 2). Electronic format.
- *Research assignment* (type 3). Writing a paper on a particular point of the syllabus, following pre-established rules on style, structure and content and employing both printed and online bibliography. Electronic format.
- *Synthesis assignment* (type 4). Creating a poster on any topic of Lesson Plan III. Printed and electronic formats (A1 dimensions).

Finally, the third stage suggested by Anderson's ACT cognitive theory is that in which behaviour execution becomes automatized. In order to achieve this level, the teaching faculty assigned to the students a series of practicals which they had to develop autonomously by means of the preparation of exercises/scripts (shell scripts) which encompass those concepts explained in the different practical sessions. Each student would hand in each problem presenting the solution in the shape of a solution/script (shell script) and a written report which described and commented on the suggested answer.

The control didactic methodology (*traditional*), applied to the corresponding groups, is based on the implementation of lecture methods and the performance of written assessment tasks to be attended at the conclusion of the instructive process.

2.5. Instruments: validity and reliability

Measurement instruments for each of the variables (Table 5) taken into account belong to two main types: (a) Data questionnaires of both an academic and sociocultural type for students; (b) Standardized tests to measure the different learning styles and (c) Multiple-answer objective tests to measure the level of conceptual knowledge in its diverse types (knowledge, understanding, application; following taxonomies such as Bloom's).

Among the different instruments employed to validate the experiment, we could mention the following:

2.5.1. Objective test pre-test

The objective test designed to assess the students' level of prior knowledge has thirty multiple-choice items with four possible answers, being only one of them true. For content and construct validity, the test has been reviewed by three specialists in the area of expertise, teachers at the University department. The result of the performed analysis of the items (difficulty and discrimination) appears in Appendix A table and a summary of its difficulty in Graph 1.

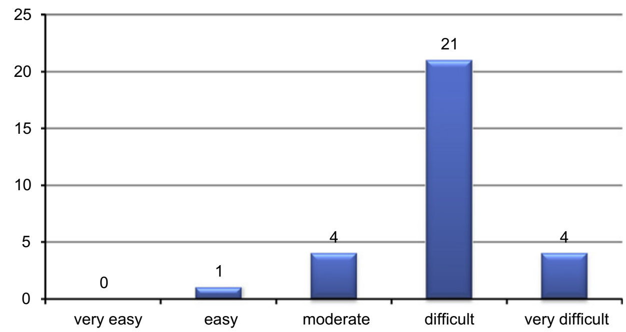
The reliability obtained by means of calculating Cronbach's Coefficient Alpha is high, with a value of 0,91. The mean difficulty of the test is 28,087%, while the mean of the test is 2,15 (in a range from 0 to 10), hence we can term it a difficult task.

2.5.2. Learning style

Multiple variables have an influence on learning processes. In the present study, it was considered necessary to control the styles of learning in the students. One of the instruments employed to identify the Learning style of subjects is the known as *Learning Style Questionnaire* (L.S.Q.) by Honey and Mumford, and later trans-

Table 5
Variables and instruments.

Type of variable	Variable	Instrument
Dependent	– Level of theoretical knowledge on the contents of Computer Science	– Objective test pre-test
	– Level of skill in the use of computing tools	– Estimation scale/Control list (Observation)
	– Satisfaction of students towards methodology	– Questionnaire (Likert Scale)
	– Final subject grade	– Final grade in list
Independent	– Learning methodology (experimental and traditional)	– Ad hoc questionnaire
Modulative or control:	– Sex, age, motivation, expectations, previous academic performance (access tests...)	– CHAEA (Honey and Alonso)
	– Learning style	
	– Attitude (beliefs, affectivity)	– Questionnaire (Likert scale)



Graph 1. Item distribution (number of items) by level of difficulty.

lated as CHAEA by Honey and Alonso, which is based on learning theories of a cognitive type. It comprises 80 items, twenty for each style (active, reflexive, theoretical and pragmatic).

According to Alonso et al (1994) learning styles are the cognitive, affective and physiological characteristics which serve as relatively stable indicators of how the students perceive, interact and respond to their learning environments. It is difficult to find in a person the different styles in pure state, for there are usually a combination of them. Nevertheless, there exists a direct opposition between concrete and abstract, between reflexive and active, so that two are predominant in each subject, not of each one of the abovementioned pair, but of one of the subsequent combinations: concrete-reflexive, concrete-active; abstract-reflexive and abstract-active. Honey and Mumford (1986), however, consider four learning styles: active, reflexive, theoretical and pragmatic. Table 6 describes the characteristics which belong to the subjects according to the learning style they present; though certainly the ideal would be for all to be capable of experimenting, reflecting, formulating hypothesis and testing them.

2.5.3. Satisfaction questionnaire

In order to record the level of satisfaction among students on the employed didactic methodology a satisfaction questionnaire was passed. Answers are valued on a five-point Likert scale. Value 1 would be "strongly disagree" and 5 "strongly agree", with intermediate degrees. Instances of the items would be: "*I am satisfied of having taken part in this experience*" or "*I would recommend making reviews also in other subjects*".

3. Data analysis

Data analysis was conducted by means of the SPSS 19.0 programme (campus licence of the University of Salamanca). Depending on the nature of variables, the applied statistical analyses were of the following kind: descriptive (central tendency and dispersion measures) and inferential (t-tests of mean difference for independent and correlated samples, analysis of variance, in the case of more than two groups in the independent variable and non-parametric tests when the conditions are not met), based on the specific objectives of this stage of the study.

Table 6
Learning styles: Characteristics; developed from Alonso et al. (1994).

Pragmatic	Theoretical	Reflexive	Active
Experimenter	Methodical	Balanced	Animator
Practical	Logical	Conscientious	Improviser
Direct	Objective	Receptive	Discoverer
Efficient	Critic	Analytical	Daring
Realist	Structured	Thorough	Spontaneous

4. Results

As a result of the analysis performed on the obtained data we subsequently present a preview of the attained results differentiated in both groups: control and experimental. Hence, firstly, the results obtained in the pre-test stage will be displayed, followed by those corresponding to the post-test stage on academic years, 2007–2008 and 2008–2009.

4.1. Results in the pre-test stage. Description and contrast of intergroups

For the academic year 2007–2008 we examined if there existed statistically significant differences (n.s. 0.05) in the **pre-test** (level of prior knowledge) and we found that **there were** differences (Table 7) in favor of the experimental group ($t = -2.834$, $p = 0.006$). If we take into account all five degrees ($F = 7.070$; $p = 0.000$), it is confirmed that differences appear between ITIM (group A and B = 0.93, = 0.68) and ITIG (=2.02), and between AT (=1.05) and ITIG (=2.02). This fact triggers the need to implement a co-variance analysis in the post-test stage, so the effect of the variable "prior knowledge" on the dependent variable of the study is eliminated.

Subsequently, we present the results of the pre-test contrast of one of the control variables: learning styles (measured with the CHAEA Honey and Alonso questionnaire to assess learning styles, Table 8). As can be observed in the following table, there are no statistically significant differences according to groups (n.s. 0.05). In both cases, experimental and control, the higher mean values were obtained in the active style and the lower in the reflexive one.

In the following academic year, 2008–2009, and under the light shed by the results of the **pre-test** data analysis, it can be ascertained that there are no statistically significant differences (n.s. 0.05) according to the studied groups ($t = 0.522$; $p = 0.603$; Table 9).

Concerning learning styles, in the year 2008–2009 (Table 10) there were no statistically significant differences either (n.s. 0.05). At a sample level, in this case, higher mean values do differ, hence in the experimental group they correspond to the pragmatic style and in the control group to the theoretical one. Nevertheless, in both cases, the lower mean belongs to the reflexive style.

4.2. Results in the post-test stage. Summative assessment phase

In the year 2007–2008, in the **post-test** contrast (final performance test), **there are no statistically significant differences** (see Tables 11 and 12) according to learning methodology ($F = 4.491$; $p = 0.232$), with n.s. 0.05.

In the same manner, in the academic year 2008–2009 it was also observed that there were no statistically significant differences between the groups according to the learning methodology applied in each case in the **post-test** (Table 13). However, if we consider these five degrees independently there do exist some differences ($F = 8.765$; $p = 0.000$), between ITIG ($\overline{X} = 4.31$) and AT ($\overline{X} = 1.79$) and between ITIG and ITOP ($\overline{X} = 1.84$).

On the other hand, if we take into account the final grade of the subject in which the teacher assesses all the recorded information on the student (tests scores, work group, presentations, etc.) we do obtained statistically significant differences (n.s. 0.05) between the control and experimental groups, the experimental being the favored one (Table 14).

With regard to the second dependent variable which was taken into account in this study, students' **satisfaction**, we highlight that, despite the fact that there are no statistically significant differences according to group, in the year 2007–2008 there is evidence of a greater satisfaction in the experimental group, as can be observed in the following graph (Graph 2).

Table 7
T-test for pre-test independent samples, according to group (control-experimental) Year 2007/2008.

	Experimental ($n = 27$)		Control ($n = 72$)		Independent *T*-test	
	$\overline{X}$	s_x	$\overline{X}$	s_x	*t*	*p*
Pre-test score	0.92	0.87	1.53	1.13	−2.834	0.006

Table 8
T-test for pretest independent samples (learning styles), according to group (control-experimental) Year 2007–2008.

Learning style	Experimental ($n = 45$)		Control ($n = 71$)		Independent *t*-test	
	$\overline{X}$	s_x	$\overline{X}$	s_x	*t*	*p*
Active	27.60	3.974	26.77	4.064	−1.075	0.285
Reflexive	24.60	3.677	24.75	3.636	0.211	0.834
Theoretical	26.44	3.696	26.72	3.642	0.392	0.695
Pragmatic	26.51	3.635	26.31	4.173	−0.266	0.791

Table 9
T-test for pre-test independent samples, according to group (control-experimental). Year 2008/2009.

	Experimental ($n = 27$)		Control ($n = 67$)		Independent *T*-test	
	$\overline{X}$	s_x	$\overline{X}$	s_x	*t*	*p*
Pre-test score	0.919	0.880	1.023	0.877	0.522	0.603

Table 10
T-test for pre-test independent samples, according to group (control-experimental). Year 2008–2009.

Learning style	Experimental ($n = 27$)		Control ($n = 73$)		Independent *t*-test	
	$\overline{X}$	s_x	$\overline{X}$	s_x	*t*	*p*
Active	26.59	2.735	26.94	2.719	0.560	0.577
Reflexive	24.59	4.069	25.75	3.086	1.492	0.139
Theoretical	26.41	3.724	27.06	2.724	0.941	0.349
Pragmatic	27.00	5.144	26.33	2.831	−0.810	0.420

Table 11
Analysis of co-variance on post-test score, according to group (control-experimental). Co-variable: prior knowledge or pre-test score. Year 2007/2008.

Origin	Type III Sum of Squares	*gl*	Squared mean	*F*	*p*
Corrected model	67.527[1]	2	33.763	10.906	.000
Intersection	99.425	1	99.425	32.116	.000
Pretest_score	43.918	1	43.918	14.186	.000
Group	4.491	1	4.491	1.451	.232
Error	235.279	76	3.096		
Total	897.936	79			
Corrected total	302.806	78			

[1] R square = 0.223 (R corrected square = 0.223)

Table 12
T-test for post-test independent samples, according to group (control-experimental). Year 2007/2008.

	Experimental ($n = 45$)		Control ($n = 52$)		Independent *T*-test	
	$\overline{X}$	s_x	$\overline{X}$	s_x	*t*	*p*
Post-test score	2.8671	1.93458	2.3508	1.84961	−1.342	0.183

However, in the academic year 2008–2009, with respect to students' satisfaction it can be emphasized that there do exist differences in the items "I felt satisfied studying this subject" ($t = -3.516$; $p = 0.01$) and "I would recommend this kind of methodology in other subjects" ($t = -3.314$; $p = 0.001$).

5. Discussion and conclusions

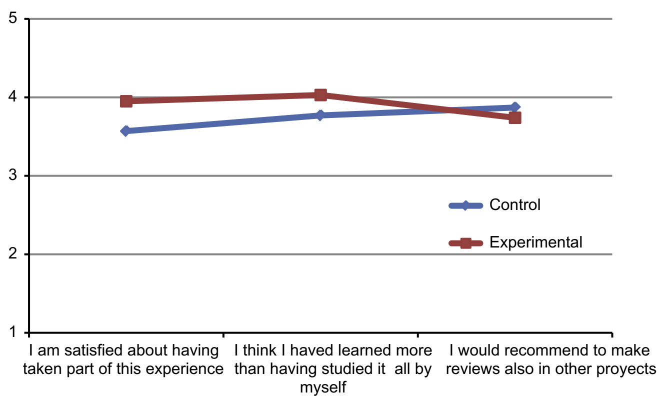
In summary, our results demonstrate that: (a) the reaction of students' towards the course is positive; (b) students have learnt at a declarative level the required knowledge in an essential subject; (c) students have acquired skills related to the defined compe-

Table 13
T-test for post-test independent samples, according to group (control-experimental). Year 2008/2009.

	Experimental ($n = 23$)		Control ($n = 31$)		Independent *T*-test	
	$\overline{X}$	s_x	$\overline{X}$	s_x	t	p
Post-test score	2.38	1.197	2.860	1.717	1.140	0.260

Table 14
T-test for post-test final grades of the subjects. Independent samples, according to group (control-experimental). Year 2008/2009.

	Experimental ($n = 25$)		Control ($n = 59$)		Independent *t*-test	
	$\overline{X}$	s_x	$\overline{X}$	s_x	t	p
Post-test scores: final grades	6.712	1.742	5.278	2.069	−3.036	0.003



Graph 2. Differences in satisfaction, according to group.

tencies; and (d) students display a transfer of the acquired knowledge in the execution of practical activities. Both the level of the students' satisfaction and the level of learning acquired by them are in line with the results attained in two consecutive academic years; a fact that indicates the consistency of the chosen design and of the obtained results.

As for the worth of these results, we consider that they can contribute to present empirical evidence which would facilitate the reflection on the didactic approach that more efficiently supports the enhancement of learning in engineering. On the other hand, the methodology we have employed, based on "the experience of a teaching methodology founded on active learning", facilitates a greater share of responsibility from the student when facing the learning process, a greater motivation, and a more satisfactory final result for all those involved in the process.

It is nevertheless true that the use of experimental methodology in educative contexts entails problems of internal validity which must be recorded and reduced, among them the effect of control of extraneous variables not included in this study.

As we are currently ascertaining through the results of empirical studies conducted by our research group at the University of Salamanca, Spain (GRIAL, http://grial.usal.es/grial/), a greater production of this kind of work is required, springing from interdisciplinary cooperation among experts in engineering, educative technologies and education. Research on the impact of Information and Communication Technologies on higher education learning is a necessary task in which blended research methodologies must be applied; a methodology based on empirical evidence which provides a theory adapted to the new educative reality which we now face.

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Appendix A

Table A1
Analysis of items of the objective test.

ITEM	DIFFICULTY			DISCRIMINATION	
	I. D%	I. D.	Grade	RBP	Grade
1	22.22	0.22	Difficult	0.48	Acceptable
2	85.00	0.85	Easy	0.17	To be revised
3	52.99	0.53	Moderate	0.70	Satisfactory
4	18.80	0.19	Difficult	0.40	Acceptable
5	44.44	0.44	Moderate	0.61	Satisfactory
6	23.08	0.23	Difficult	0.43	Acceptable
7	23.00	0.23	Difficult	0.43	Acceptable
8	40.17	0.40	Moderate	0.70	Satisfactory
9	17.09	0.17	Difficult	0.34	Acceptable
10	37.61	0.38	Difficult	0.59	Satisfactory
11	5.98	0.06	Very difficult	0.21	To be revised
12	29.91	0.30	Difficult	0.61	Satisfactory
13	7.69	0.08	Very difficult	0.35	Acceptable
14	36.75	0.37	Difficult	0.50	Satisfactory
15	33.33	0.33	Difficult	0.55	Satisfactory
16	46.15	0.46	Moderate	0.70	Satisfactory
17	5.13	0.05	Very difficult	0.27	To be revised
18	29.91	0.30	Difficult	0.45	Acceptable
19	27.35	0.27	Difficult	0.49	Acceptable
20	35.04	0.35	Difficult	0.67	Satisfactory
21	22.22	0.22	Difficult	0.53	Satisfactory
22	35.90	0.36	Difficult	0.66	Satisfactory
23	38.46	0.38	Difficult	0.66	Satisfactory
24	22.22	0.22	Difficult	0.52	Satisfactory
25	38.46	0.38	Difficult	0.66	Satisfactory
26	36.75	0.37	Difficult	0.59	Satisfactory
27	12.82	0.13	Very difficult	0.77	Satisfactory
28	32.48	0.32	Difficult	0.65	Satisfactory
29	31.62	0.32	Difficult	0.61	Satisfactory
30	34.19	0.34	Difficult	0.50	Satisfactory

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