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Educational Technology in Flipped Course Design*

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The use of technology to engage students and to provide them with tools to study autonomously is increasingly frequent in higher education. This paper outlines an experimental study that analyzes the effectiveness of flipped classroom design, and argues how the use of technological, educational resources such as videos of educators teaching, interactive materials, simulators, virtual labs and game-based learning have facilitated the use of class time for active learning and discussion.

The study was conducted in several academic years with groups studying Fundamentals of Computer Technology, a core subject in the first year of the Computer Engineering and Information Systems degree courses. We analyzed data collected from online activities on a learning platform created from scratch, from classroom activities and from attitudinal and satisfaction surveys. We compared the evolution of outcomes between the 2009–2010 and 2015–2016 academic years. The methodology followed a quantitative design with control and experimental groups, and descriptive statistical techniques were used.

The results obtained show that learning achievement and performance in terms of qualifications were higher in the experimental groups, where the flipped classroom approach using technological resources was adopted, than in the control groups, where the traditional lecture approach was used. A significant positive effect on participation, engagement and student satisfaction was also identified.

Keywords: flipped classroom; online learning environment; educational technology, virtual laboratories; game-based learning; videos; mobile devices

1. Introduction

Starting higher education is a major challenge for most students, as many of them do not have a clear professional vocation and those who do have one may have idealized the studies, which do not conform to their expectations. This is particularly true of engineering and computer degrees, which usually have high dropout and failure rates. Fundamentals of Computer Technology is an ambitious subject for students whose knowledge of and interest in electronics is basically non-existent. Spanish students are able to access engineering and computer degrees with a grade of 5 in the university entrance examination, and to make matters worse, almost half of the registration for these courses is by students taking the September examination, meaning that they join the course 4 or 5 weeks later than their classmates. These degrees consequently have higher dropout and failure rates every year. These difficulties prompted us to search for new educational experiences and for information and communication technology (ICT) resources to motivate and encourage students, and to improve their educational outcomes.

There has been a great deal of discussion in the educational sphere about active learning strategies such as the flipped classroom [1–6], a type of blended learning that enables student interaction inside the classroom because they have carried out a previous and autonomous study, and about various technological learning resources such as simulators and virtual labs [7–10] which give students hands-on experience in engineering activities.

By combining learning strategies and technology resources, it is possible to create meaningful learning scenarios that increase in-depth learning and improve educational outcomes. For our study, we have created an online learning environment (OLE) from scratch, which is designed to facilitate students' self-study by integrating video teaching, interactive exercises, virtual laboratories and game-based learning.

Our main objective is to make contributions in three areas. First, an evaluation of whether the active learning approach of the flipped classroom or inverted classroom has led to a significant improvement in learning achievement. Second, to evaluate whether innovative learning tools such as virtual or online learning environments, virtual laboratories, educational videos and game-based learning techniques have had a significant impact on learning. Finally, to explore the effects of these learning resources on students' involvement and engagement in the classroom, and to analyze how they facilitate the use of active learning methodology.

The paper has been structured as follows. Section 2 contains a literature review. Section 3 presents the experimental design, the instrument, the research

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questions and the measures. Section 4 presents the results. The discussion follows in section 5. The paper ends with the conclusions obtained during the research, and future work.

2. Previous research and related works

Breakthroughs in Information and Communication Technologies offer many solutions, some of which have proved to be very effective in higher education, enhancing learning and increasing the effectiveness of teaching.

We consider the alternative to traditional learning, i.e. the flipped course design, as used in the classroom thanks to the self-learning largely arising from the use of ICT. We review three different approaches to some of these educational resources: Teaching Videos, Virtual computer laboratories or simulations, and Game-based learning.

2.1 Active learning techniques: the flipped classroom

Active learning techniques have numerous benefits, involve students in the learning process, adapt to the learner's style and provide spatial and temporal flexibility, using a "just in time—any time" approach [11]. For their implementation, students have to engage in meaningful learning activities and reflect on what they are doing [12].

In our study, we implemented the active learning approach of the flipped classroom [13], which is defined according to the Horizon Report 2015 [14] as a model that overlaps blended learning with pedagogical approaches, and where class time is devoted to learning activities based on collaborative projects.

In a Flipped Learning environment, teachers provide students with learning resources, usually video lessons; the students can work, watch or listen at home repeatedly and at their own pace and have opportunities to think about them in depth. Later, in the classroom, teachers can address problems, recognize students who are struggling, and can give these students the attention they need.

There is empirical evidence that proves the benefits and the effectiveness of active learning compared to traditional lecturing [12, 15] and many experiences and a great deal of literature concerning the flipped classroom or reverse classroom approach [2, 4, 5, 16–20]. However, with some exceptions [17, 21], the successful implementation of engineering courses continues to be minimal.

Furthermore, most of the published research about the flipped classroom, mainly uses videos or written materials to prepare students for classes. However, students want and need to carry out meaningful practical activities, especially in the academic disciplines of science, technology, engineering and mathematics (STEM) instead of simply substituting listening to a lecture with listening to a video. In order to implement the flipped approach in the classroom, we therefore introduced virtual labs, circuit simulators and game based learning in addition to the videos, as activities to be performed online by students.

The students work at home, doing online activities, watching videos and working with simulators and virtual lab activities, which has been a better starting point for a meaningful learning in the classroom where they have carried out participative and collaborative activities, using game-based learning activities based on mobile resources and apps, for example.

2.2 Teaching videos

One of the educational technology resources with the greatest potential which has been most widely used in recent years is undoubtedly the video [22]. It is used in a wide variety of ways; most obviously in distance education, but also as the linchpin in hybrid education environments as an effective tool of autonomous learning. There is general agreement that video can be a valuable tool in education. The results of many studies find videos to be an effective and useful learning tool providing significant knowledge gains [23], student satisfaction and grade improvements [24] and leading to the acquisition of significantly higher practical skills [25].

However, media such as video are not effective in themselves. To be useful, they must be embedded in appropriate instructional contexts [26, 27]. Our approach integrates video with other resources, using instructional strategy to achieve diverse learning objectives and competencies.

2.3 Virtual labs and simulators

In many areas of knowledge, but especially in eminently practical and technological fields such as engineering, students must devote much of their learning time to solving practical problems and simulating experiences. Computer simulation and virtual laboratories have been suggested as a supplementary tool for effective learning, based on the integration of technology and appropriate instructional strategies. A properly designed virtual experiment of any type can even replace real-time experimentation [28]. Many studies analyse the effectiveness of virtual labs and simulations in providing students on engineering courses with hands-on learning experiences and practical tools. For example, Harb et al. [29] report improved performance in learning basic electrical engineering concepts when using an interactive web-based circuit simulator tool. Chu and Fang [30] describe

advances in the learning process, improvements in students' motivation, and a reduction of the teaching load using a system that provides virtual laboratory practices. Sell and Seiler [31] observed an increasing in the time spent on the course by students, and more autonomy to acquire knowledge and practical experience of problem-solving in an experiment where students use a comprehensive learning concept and a context which includes virtual and remote labs in a web environment. Finally, Sastry and Ali [32] develop a virtual environment for power system modelling and load flow analysis that provides high levels of flexibility for teachers to create challenging problems with different combinations.

2.4 Game-based learning

Motivation is a fact that with a positive influence on learning [33], and as such several authors have investigated the effects of external rewards for motivating and engaging students [34–36]. Interest in game-based learning as a method to increase student enthusiasm continues to grow. Game-based learning environments have significant potential for challenging and involving students in an active learning process. Domínguez et al. suggest [37] that students who completed a gamified experience obtained better scores in practical assignments, although they also admit that they performed poorly on written assignments. Hwang et al. suggest [38] an experimental model using an online game web-based problem-solving activity, with results showing a significantly improved experience in learning attitudes, learning interest and the level of acceptance of technology among the students. Ibanez et al. [39] show positive effects on the engagement of students evaluated in a gamified learning activity, targeted at the learning of the C programming language and a moderate improvement in learning outcomes.

3. Experimental design

The higher dropout and failure rates in the first years of computer degree courses prompted the search for innovative learning tools and new learning methodologies, to enhance students' experiences and to improve learning process and educational outcomes. The various ICT mentioned in the previous research have proved to be very effective in different educational experiences. Videos and virtual labs facilitate flexibility and autonomous learning. Virtual labs or simulators are also useful for acquiring knowledge and practical experience, and game-based learning is a powerful tool for motivating and engaging students. For these reasons, we have developed an online web environment that integrates all of these resources.

Nevertheless, according to [40], the use of ICT in isolation does not improve students' experiences. An appropriate combination of ICT and interactive learning strategies is necessary to increase deep-seated learning and to enhance students' satisfaction. We therefore combined the use of ICT with a flipped course approach. This incorporated a dynamic of work in the classroom that included new strategies such as cooperative learning or active learning, proposing challenges to students and preparing scenarios where students could share and build knowledge. These learning scenarios are based on the student's self-study using the ICT.

Despite the extensive literature evaluating each of these tools separately, there is a lack of experiences that evaluate the use of these ICT tools in a flipped classroom approach, to confirm the extent to which this combination enhances education and increase the effectiveness of teaching.

3.1 Research questions

This research aimed to evaluate an academic experience that combine the flipped classroom approach with an online learning environment in three aspects. First, it analyzed the efficiency of the flipped classroom approach compared to the traditional face-to-face course approach. Second, it studied the effectiveness of educational ICT integrated in an online learning environment, evaluating whether these innovative learning tools have a significant impact on learning. Finally, it studied the effects of these learning resources in terms of the student's autonomous work and the hands-on experience facilitated by the flipped learning approach.

As regards the flipped classroom approach, we formulated the following questions:

Q1. 1. Has the flipped classroom approach led to a significant and positive improvement in students' learning experience and satisfaction compared to the traditional face-to-face approach?

Q1. 2. In terms of academic outcomes, have the students in a flipped learning approach achieved better results than in a traditional face-to-face approach?

As regards the relationship between the use of the technological resources and the flipped classroom approach, the following questions were formulated:

Q2. 1. To what extent have ICT affected the implementation of the flipped classroom approach?

Q2. 2. Which of these ICT has been the most relevant and positively meaningful?

Data from various sources was collected and analyzed to answer these questions, including question-

naires that were developed and sent to the population indicated in section 3.2. The first survey was carried out at the beginning of the course to find out about the students' willingness to use ICT tools and participate in an active learning approach. The last survey was conducted upon completion of the course, the aim was to measure students' perceptions and opinions about OLE tools and about the flipped classroom approach.

In addition, the academic outcomes were analyzed over several years to compare groups where the OLE and the flipped approach were developed alongside others in which traditional learning methodology was used.

3.2 Study site

The study was conducted during the 2013–2014, 2014–2015 and 2015–2016 academic years in the Fundamentals of Computer Technology course, a first term subject taught in the first year of the Computer Engineering and Information Systems degree courses, which have the fundamental goal of understanding the basic operating level of a computer. The course studies the processing of binary data (bits) at different levels of abstraction, from logic gates to basic electronic devices, and provides an introduction to functional units at the architectural level.

Students have 2 hours of lectures and 2 hours of practical laboratory sessions every week, which are complemented with prior work on the OLE platform. Table 1 Shows the number or students in experimental and in control groups. The format of the experimental groups changed during the different academic years for organizational reasons.

3.3 Instrument

We used the flipped classroom approach in the last three academic years, and used several ICT to provide students with autonomy to study online and to work actively in the classroom. The main instrument was the OLE, an online learning environment created from scratch specifically for the subject Fundamentals of Computer Technology, and designed to provide students with hands-on experience as well as autonomy in learning, by integrating video, interactive exercises, virtual laboratories and game-based learning. The OLE is an enjoyable way to study independently and to practical sessions that reinforce the content and explain some complex concepts. The educational material used followed a pedagogical approach that makes it easier for students to study before class time, at their own pace, meaning that in the classroom, there is more time to apply the knowledge acquired to solving problems, which is especially meaningful expertise on technology courses.

Accessing and working on the OLE platform allow students to obtain medals by completing various challenges and learning stages related to the skills they have acquired. The OLE was also designed to facilitate the use of learning analytics to extract information about which activities or content are more complex for the students, and to enable assessment of the students to determine which activities each student has carried out, when, and the success rate.

3.3.1 Videos in OLE

The purpose of the video is to stimulate students' attention, motivate them to study, increase understanding and create opportunities for debate. There are around twenty videos on the OLE, between 5 and 10 minutes long, with embedded questions to establish the contents and to raise the student's interest. Students cannot advance through a video and it will not display the activities associated with it until the video has been completed. Students earn points for displaying each video and correctly solving the associated exercises. Adding new videos, removing them or including new exercises in each of them is very simple. The OLE videos are created by the teacher using various methods - by capturing the computer screen, working with a computer program, with a specific software tool or using a tablet or PC, although most videos were made showing the image of the teacher explaining how to solve specific procedural problems, because numerous studies highlight the importance of eye contact, gestures and facial cues in attracting attention and enhancing performance [41, 42]. This kind of video increases students' involvement and creates a conversational atmosphere similar to the typical relationship in an individual tutoring session, like sitting in a front row seat.

3.3.2 Activities and Virtual labs in OLE

In technological disciplines like engineering, students expect technology to be used as an active experimental and training and learning tool. The OLE platform offers virtual labs and simulation, randomly generated graphics activities, numeral

Table 1. Experimental and control groups size

2013–2014		2014–2015		2015–2016	
Experimental N = 113	Control N = 42	Experimental N = 139	Control N = 21	Experimental N = 82	Control N = 96

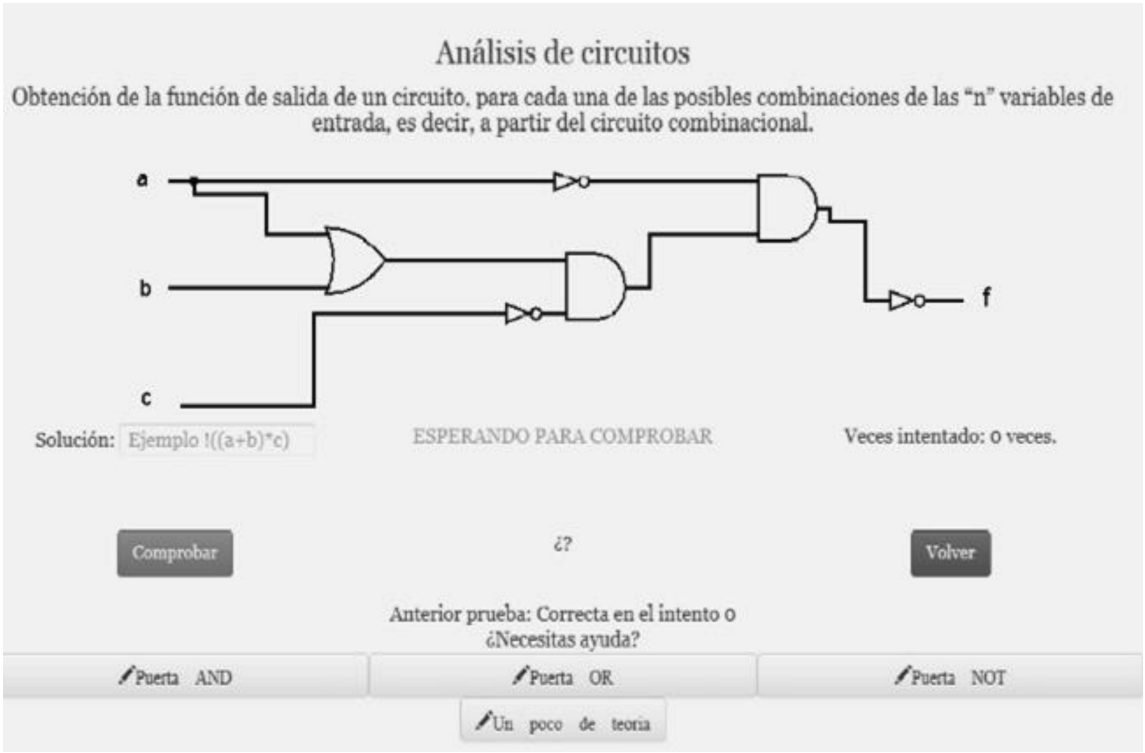

Fig. 1. Combinational circuit exercises.

Fig. 2. Badges in numerical system exercises.

systems exercises, truth tables, circuit simplification exercises, Karnaugh maps, minterms and maxterms of different number of variables, circuit simulation exercises, analysis and synthesis of circuits, logic gates and integrated circuits exercises, operations with the memory system, address, data and control buses, and a simulator of an Eprom memory recorder for carrying out various activities.

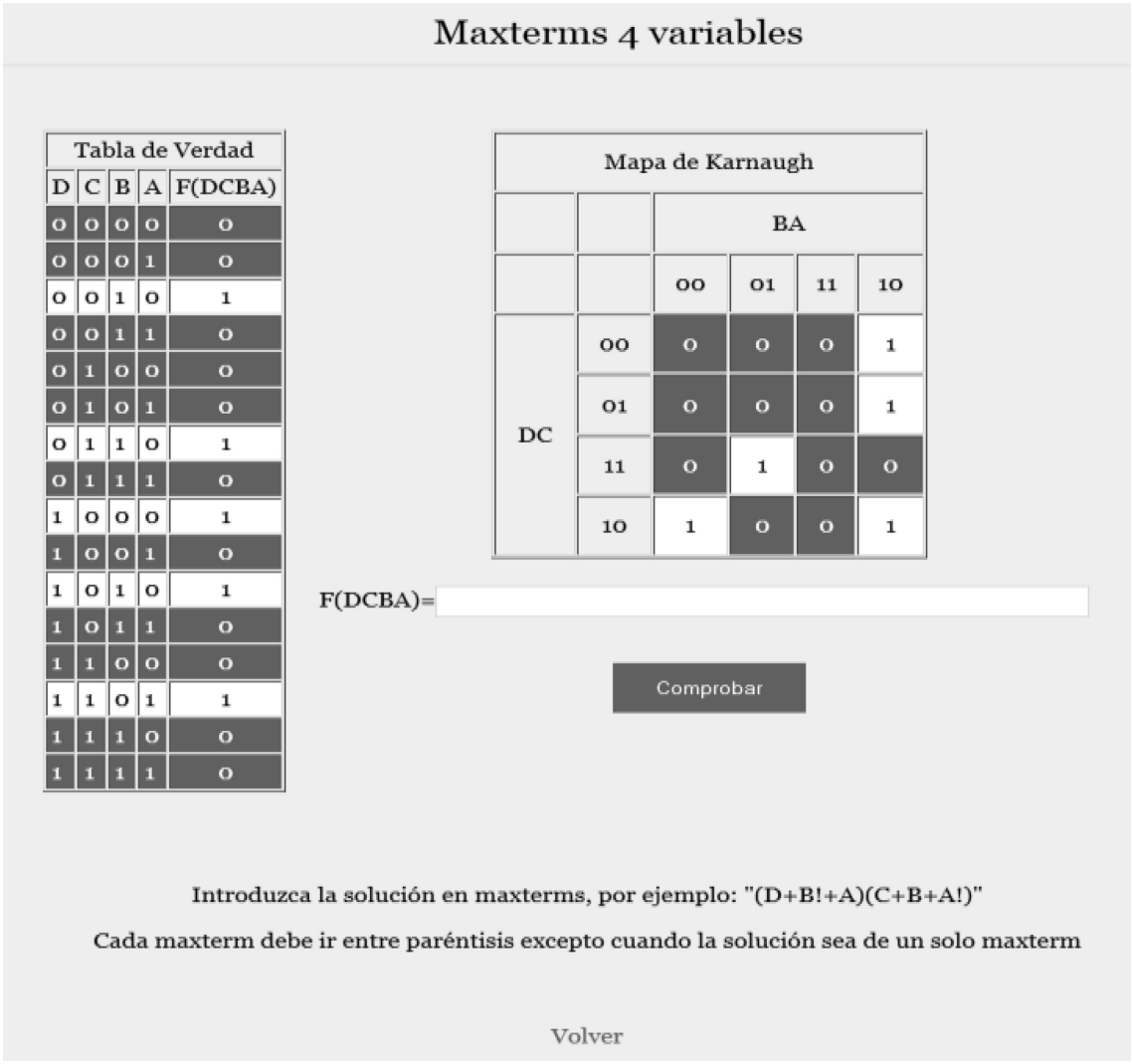

Fig. 3. Karnaugh maps exercises.

Figures 1–4 show some of the activities available in OLE. The structure of all the activities is highly homogeneous; there are three attempts and if the student fails, the solution is shown and a new randomly generated exercise appears. To obtain a medal as an expert, e.g. in minterms, the student must perform three correct exercises consecutively on minterms of 2, 3 and 4 variables.

All the work done is stored in a database to analyze and to assess the work done by the student. Students can see the status of their medals and points partially and globally, and compare their progress with the results of the group.

3.3.3 Playing with mobile devices in the classroom

A series of activities to complete and videos to watch was scheduled each week. As a result, thoughtful and participatory activities were carried out in the classroom based on a few minutes of self-study. In the first year, the students raised their hands to answer direct questions from the teachers, and worked in small groups and as individuals. However, it was hard to manage, register and therefore measure the individual students' work. We wanted an activity that was easy and quick to carry out in the classroom and which could be accessed for visible results immediately. The solution was to use mobile devices, smartphones or tablets, which are used increasingly in the classroom. For our particular scenario, we used several tools, including Kahoot [43], a free, easy and intuitive utility perfectly suited for use in the classroom. The access code, questions and results are projected on the screen and responses can be entered from any device with a display of large buttons with colors and geometric shapes. The results can be displayed immediately on the screen, and can be retrieved as a spreadsheet. Another application used was Socrative [44], a free application with an impending payment option, which is also accessed by code

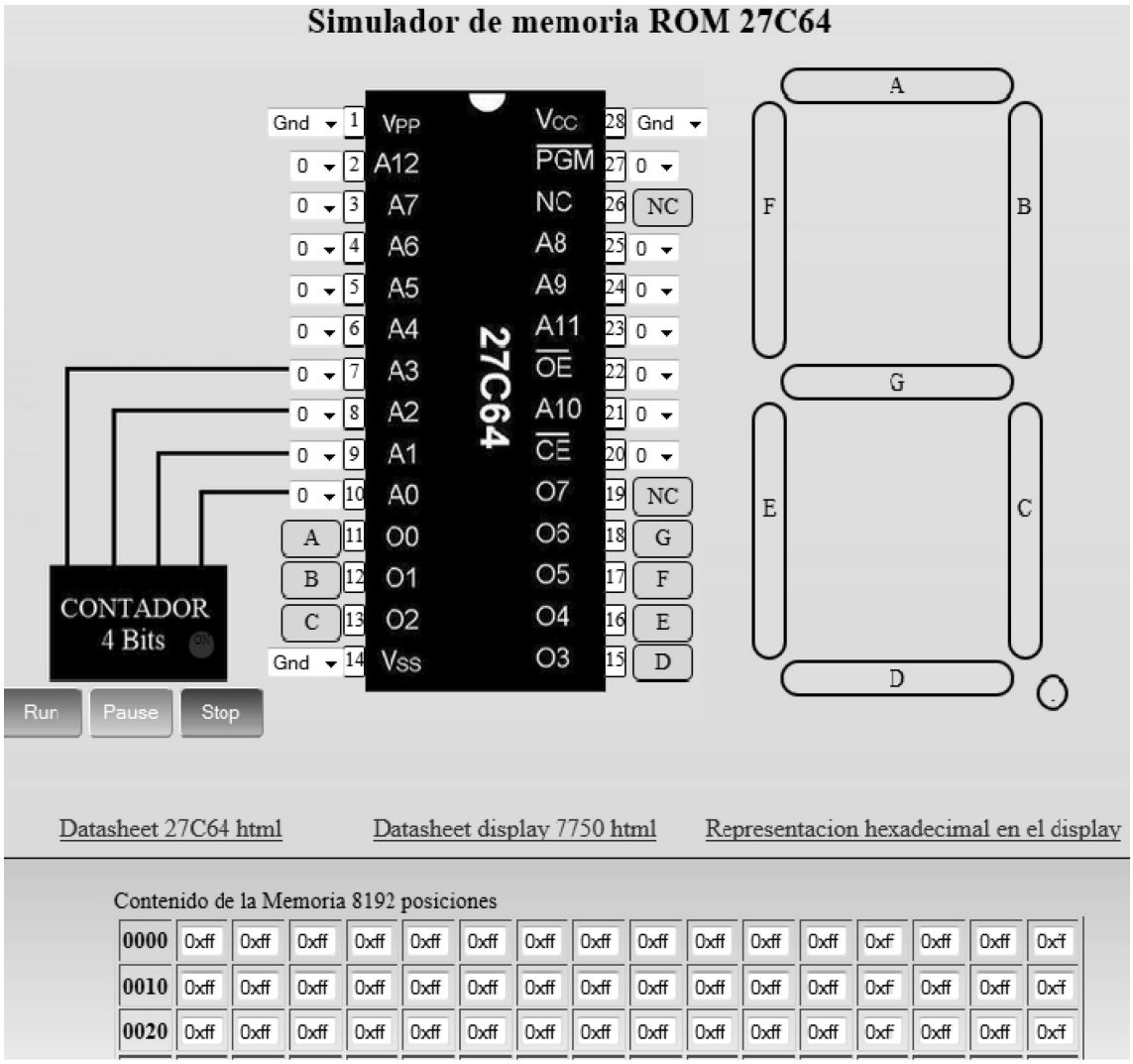

Fig. 4. Memory system exercises

and also allows results to be retrieved, although it is somewhat more complex to use than Kahoot and its interface is less attractive. The classroom activities had limited impact on students' grades. They were aimed at motivating classroom participation and prior study. To prevent students from cheating, a competitive strategy was used quite successfully, with a fixed number of points being awarded for all the correct answers or points awarded according to a ranking of correct answers. The amount of points awarded was also related to the difficulty, so that easy questions earned few points, while difficult questions gave a substantial rewarded to the few students ones who answered correctly. This method also highlights general problems of understanding, and helps students express themselves more freely.

3.4 Methodology and measures

Voluntary and anonymous surveys were carried out to answer the questions raised. The first survey was conducted at the beginning of the course, and its purpose was simply to determine the initial knowledge of students and their willingness to use OLE tools and active learning techniques. The questionnaire features a number of detailed questions, some requiring simple multi-choice responses about the student's background, their previous knowledge and their interest in the subject matter. Other questions were related to the use of ICT tools or were related to active learning methodology. If they had ever used it and what was their experience and opinion. There was also an open question: Is there anything else you would like to say?

The last survey was conducted upon completion of the course, and had two main objectives: to obtain feedback and determine the degree of satisfaction with the flipped classroom approach, and to assess students' satisfaction with OLE tools. The instrument used was a voluntary and anonymous questionnaire based on the five-level Likert scale.

With 8 items related to the OLE tools and 7 items related to the Flipped classroom approach, the questionnaire is like others used by other investigators [30, 37, 45]. The response options were: 1. Strongly disagree, 2. Disagree, 3. Neither agree nor disagree, 4. Agree 5. Strongly agree. The questionnaire also included an open-ended question which required qualitative answers: Do you have any comments or any suggestions?

The academic results for the past seven academic years have also been analysed. Learning was based on the traditional classroom lecture approach from 2009–2010 to 2012–2013, while the flipped classroom approach was implemented in the 2013–2014, 2014–2015 and 2015–2016 academic years, and supported using the educational technology analyzed in this study.

The evolution of the subject under study was compared with the evolution of different subjects over the years to minimize the potential threats to internal validation, and to rule out alternative explanations for the improvement in the last two years' academic results.

The results for the experimental groups and control groups were also compared. In the experimental groups, the students used the OLE learning platform and the Flipped Classroom approach, while in the control groups the traditional face-to-face approach using lectures as a learning strategy was adopted. Although random assignment in experimental and control groups to provide external validity would have been desirable, this was not possible because of institutional allocation. However, we endeavour to make all the parameters as similar as possible.

Ethics questions were considered in the study, the students were informed about the activities and the questionnaires and all data were treated anonymously.

All the analysis was performed using the open source project R [46].

4. Results

Questionnaires are one of the standard data sources, although this study also considered other data, such as those registered within the OLE learning environment, data from the activities carried out in the classroom and academic outcomes over several years.

4.1 Questionnaires.

In this article, we focus on the questionnaires applied in the 2014–2015 course, because in the 2013–2014 course they only aimed to obtain student feedback about the OLE and the Flipped approach, and although the response was very positive, non-validated questionnaires were used. In the 2015–2016 course, the surveys carried out measured issues which are themselves the subject of a separate study.

4.1.1 Students' initial willingness to use the OLE and to participate actively in classroom

The first survey was voluntary and anonymous, and was answered by 117 of a total of 139 students. The information collected was useful in determining the starting point and students' interest in the course contents, tools and the active learning approach.

40% of students had used video as a learning tool while 60% had never done so. 83% thought it was a good alternative for following classes more actively, while the other 17% considered it was more useful as an option for study prior to the assessment. All the students were interested in using the OLE tools. As regards active and participatory learning in the classroom, 63% said that it seemed the best way to learn, 27% said it was a good idea as long as did not involve much effort, 7% had no interest and would prefer the teacher never to ask them and 3% replied "do not know, no answer". 16 students answered the optional open question: 14 were positive or very positive responses: of which, 6 were, mainly, relative to the use of videos. The other two responses were: "I do not like to participate because of shyness" and "everything is explained very fast".

All this information was considered a good starting point for implementing the active learning methodology and for using the developed online learning environment.

4.1.2 Attitudinal survey

The survey conducted after completion of the experience was more important, as the students' perceptions and opinions are key aspects in defining the quality and efficiency of the tools and methodologies used. The survey was conducted several weeks after the end of the term, and as a result only 46 students completed it. This was mainly because it was anonymous and voluntary, and after the end of the term, students move on and devote themselves to the new challenges of new subjects.

The Cronbach's alpha was calculated to measure the internal consistency of the survey. Cronbach's alpha was 0. 8769 for questions concerning the use of the OLE virtual learning platform, and it was 0.8365 for questions about the course and about the Flipped classroom design. According to Straub [47] if the value is greater than 0.7 it is a reliable questionnaire, indicating that our questionnaire is highly reliable and moreover, the values are lower than 0.95, and according to Straub et al. [48] values above this level would suggest that the students are not responding naturally.

Table 2 shows the questions and the summary of

Table 2. Questions and results of the attitudinal survey

Questions relating to the OLE and its learning tools			
	mean	**stdDev**	**stdError**
OLE1 The content and instructional design was presented effectively.	4.587	0.580	0.0855
OLE2 Using the OLE was simple for me.	4.674	0.519	0.0765
OLE3 I found the Videos useful and effective as a learning tool.	4.783	0.467	0.0689
OLE4 I found the exercises and interactive activities useful to acquire skills in the subject	4.565	0.620	0.0914
OLE5 I found the use of medals and points motivating.	4.109	0.900	0.1327
OLE6 I found study using the OLE interesting and entertaining.	4.543	0.585	0.0863
OLE7 Using the OLE improved my experience with the subject	4.565	0.544	0.0802
OLE8 Using the OLE helped me bring the subject up to date and to be more active in the classroom	4.022	0.683	0.1007
Questions relating to the Flipped Classroom active learning methodology			
	mean	**stdDev**	**stdError**
FLIP1 My level of involvement with the subject was high.	4.391	0.649	0.0957
FLIP2 The participatory activities and exercises in the classroom were useful and effective.	4.543	0.585	0.0863
FLIP3 The amount of activities in the classroom seemed appropriate to me.	4.217	0.629	0.0928
FLIP4 The activities and exercises in the classroom helped to create a better working environment.	4.152	0.698	0.1029
FLIP5 It is positive that the participation of students in the classroom was valued.	4.130	0.653	0.0963
FLIP6 I would like to learn more about the subject.	3.783	0.814	0.1200
FLIP7 This was a worthwhile learning experience.	4.696	0.465	0.0686

the survey results. These values show that experience and appreciation of both the OLE learning environment and the active strategies implemented in the Flipped classroom approach were undoubtedly positive.

In OLE issues, the item with the lowest value, but which was nevertheless very high, was the item OLE8: ''using OLE helped me bring the subject up to date. . .'' showing that many students did not use OLE as required, prior to the classroom time, so the contents could be discussed in the following class, but instead only used it as a study tool for the assessments. This data is also reflected in other analysis, in classroom participation and of course in the access dates for the various activities.

Considered individually, the OLE resources most highly rated were the OLE3 videos, followed by the OLE4 activities and finally the OLE5 gamification and the use of medals.

In the questions about the flipped classroom approach, the item with the lowest rating was FLIP6: ''I would like to learn more about the subject''. Although the experience was positive, this subject is complicated and ambitious for the first term, as reflected in the high number of failures. In fact, in an open-ended question many students said that the contents of the subject were not very interesting for them, although many also said that they liked the course more at the end than they had thought at the beginning, mainly because of the use of the OLE virtual learning environment and the learning approach.

As for the qualitative data collected in the open question on suggestions, the excellent reception of the OLE by the students is interesting: ''The OLE is very valuable to study'', ''It helps me to understand the subject and to pass the course'', ''The OLE is a great help to study daily and review for exams'', ''It is useful to bring the subject up to date''.

Many of the answers were concerned, in particular, with the videos, some students were very grateful for the videos ''the videos are the best part of OLE'', ''do not stop recording videos'', ''I hope they were used in more subjects'', ''the videos allow to see explanations'', others emphasized the flexibility that videos provide, ''thanks to the videos I understood the subject'', ''you can study, stop, rewind and take notes''.

Although the practical exercises were also one of the points most appreciated by the students, nothing was specifically referred to the virtual laboratories and only one student mentioned that found amusing the use of badges. Therefore, the video was considered the most valuable OLE tool, Q2.2, because it allows to follow the explanations at the pace and convenience of each student.

There were also many very positive responses regarding the active learning model employed, ''the method used in class engaged me in the activities and learning'', ''the classes were very dynamic''.

4.2 Analysis of academic results over several courses

These analysis attempt to answer the questions related to flipped classroom approach, Q1.1. and Q1.2. To do this, an analysis of academic results between the 2009–2010 and 2015–2016 academic years was carried out first, comparing both average grades and the percentages of students passing. A comparison was made between the results for the degree in Information Systems, because during those years there was no substantial changes in the syllabus, assessment method, laboratory or teacher.

Table 3. Average grades

Year	Students	Average
2009–10	63	3.63
2010–11	86	3.60
2011–12	81	3.86
2012–13	92	3.81
2013–14	76	4.68
2014–15	81	4.71
2015–16	56	4.72

The only differential variable was the Flipped classroom approach and the use of ICT integrated in the OLE during the 2013–2014, 2014–2015 and 2015–2016 academic years, while in the previous years the traditional learning approach based on lectures was used.

The graph above shows a significant improvement in the results in the last three years, when active learning techniques and ICT were used. On these experimental courses, the grade averages were 4.68, 4.71 and 4.72 while in the previous years they ranged between 3.6 and 3.86.

Figure 6 shows the percentage of students passing not only the subject Fundamentals of Computer Technology, but all the first-term subjects in various years to rule out an alternative explanation for the improvement as a result of chance, due to a higher level of students these years.

In the subject studied, Fundamentals of Computer Technology, there is a clear improvement in the pass rate in the last three academic years. Other subjects such as Statistics had good academic results in 2013–2014, but not in the last two years, while the subject Mathematical Fundamentals had very good outcomes in 2015–2016 but not in 2013–2014, and in the other subjects there was no improvement during those years, which means that alternative explanations can be ruled out.

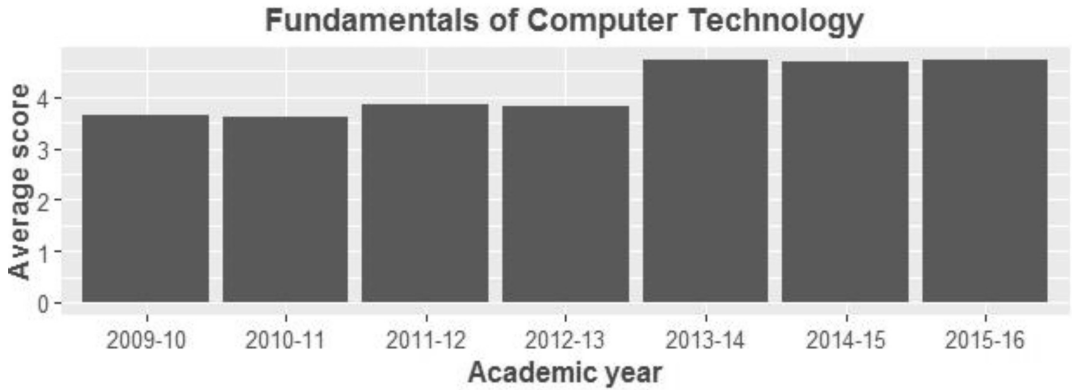

Fig. 5. Average grades over the years

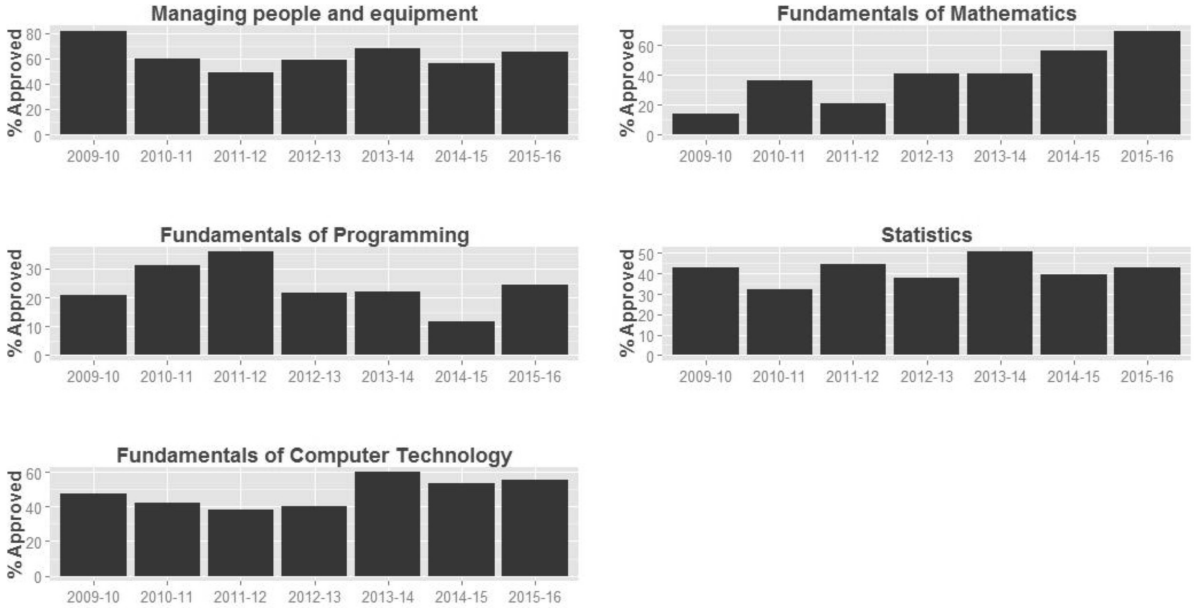

Fig. 6. Comparison of the percentage of students passing in different subjects over the years.

Table 4. Academic results. Comparison between experimental and control group grades

	2013–2014				2014–2015				2015–2016			
	Experimen. N = 113		Control N = 42		Experimen. N = 139		Control N = 21		Experimen. N = 82		Control N = 96	
	N°	%	N°	%	N°	%	N°	%	N°	%	N°	%
With distint.	3	2.65	1	2.38	3	2.16					1	1.04
Outstanding	2	1.77			3	2.16			2	2.44	1	1.04
Good	26	23.01	13	30.95	35	25.18	5	23.81	27	32.93	15	15.62
Pass	31	27.43	6	14.28	34	24.46	3	14.29	18	21.95	25	26.04
Fail	44	38.94	19	45.23	56	40.29	13	61.90	27	32.93	43	44.79
Dropped out	7	6.19	3	7.14	8	5.75			8	9.76	11	11.46

4.3 Comparative experimental group and control group

To reduce threats to internal validity experimental groups were compared with control groups in the 2014–2015 academic year and in the 2015–2016 academic year. The only differential variable was that the flipped classroom approach with ICT was used in the experimental groups, while the traditional lecture approach was used in the control groups. The syllabus, assessments, laboratory practical sessions and other variables were identical.

Table 4 shows that in the three courses the academic results in the experimental groups were better than in the control groups in both academic years. Percentages of students that passed the course in experimental groups were 2013–2014: 54.87, 2014–2015: 53.96% and 2015–2016: 57.32% and percentages of students that passed the course in control groups were 2013–2014: 47.62 2014–2015: 38.09 and 2015–2016: 43.74%

5. Discussion

Our research contributes to the ongoing discussion in the literature on the evaluation of modern educational technologies, and the active learning pedagogy of the flipped classroom, and essentially asks whether they can engage and motivate students and achieve better learning outcomes, and if these technologies help to create the flipped classroom approach.

Autonomous and virtual learning is increasingly widespread in higher education while practical hands-on experimentation is necessary in engineering studies. Many educational researchers have reported the benefits they experienced using ICT such as videos [23–25], virtual labs [29–32] and game-based learning [37–39].

Our approach integrates teaching videos in an online web environment in an appropriate instructional context, as mentioned in [26, 27], with virtual laboratories and simulators covering the contents of Fundamentals of Computer Technology and gamifying all the activities, enabling students to earn experience points, badges, and awards in order to "level up" through the curriculum by completing different stages in order to motivate autonomous study and create an active learning environment in the classroom. This had a significant effect on the improvement of academic results and students' satisfaction.

Additionally, the flipped classroom design was highly rated in our study, as well as by other educational researchers [2, 4, 5, 16, 17]. In addition to the increase in involvement and engagement with the subject, higher and better quality interaction among students and between students and teacher took place, as reported by Battaglia and Kaya [17]. The flipped classroom is a teaching strategy that is inherently designed for increasing the instructor's accessibility and availability, and this leads to greater confidence among students to intervene, to ask questions and to give answers.

Game-based learning has been used not only in activities in online learning environments, but also in the classroom, using mobile devices to carry out activities. These activities encourage every student to participate, and allow students to be active in their learning process [49] and are even useful for showing the level of students' understanding, whether any students are struggling, and if early actions are required.

The analysis of the academic results over several academic years and the comparison between the experimental and control groups suggest an affirmative answer for the research questions concerning the efficiency and the effectiveness of the flipped classroom approach in terms of the improvement in learning (Q1.1) but the positive answer is clear in terms of grades (Q1.2). The ratings in the questionnaire also show that the experience and appreciation of students related to both the active strategies implemented in the Flipped classroom approach and the OLE learning environment and its tools were certainly positive for learning and for the results obtained.

As for research question Q2.1, although there is a positive relationship between the OLE score and the classroom involvement, the model is limited and the result is poor. However, in the qualitative answers to the survey, the students said that using the OLE and its tools facilitated the flipped classroom approach and participation in the classroom.

Finally, for research question Q2.2, video was the most highly rated educational resource in our project. Most students rated it a useful tool, which is very helpful for complex topics, which can be watched, paused and repeated until information is understood or a skill is mastered.

The students' feedback indicated that they prefer this novel learning method of the flipped classroom, using a gamified online learning environment with virtual labs, interactive materials and videos rather conventional course structures. However, our learning approach may be more useful for students who are more highly motivated or whose learning style is more suitable for tools and methodologies of this type, since the flipped classroom approach requires commitment from the students and prior work in order to submit reflections, questions, and concerns, so the major concern was related to students not completing the work they needed to complete at home. In many cases, students watched videos and performed activities just before the exam, and flipped learning is not a solution that remedies this issue. This is certainly the main challenge, to motivate students to acquire greater responsibility, outside the classroom with a reflective self-study and in the classroom taking active part in their learning. In order to minimize this problem, the students were awarded with points that were more symbolic than significant for carrying out activities in the classroom.

We noticed not only an increase in involvement and interaction in the classroom, but also an increase in students' participation and interaction outside the classroom, e.g. in tutorial hours, and by means of e-mails. The relationship established between the students and teacher in the flipped classroom approach helped students to feel more relaxed and self-confident when asking for explanations when they did not understand something. The relationship among students was also enhanced. The flipped classroom approach encouraged meaningful learning communities to work together. This was possible thanks to the increased opportunities for interacting with each other in a learning environment with greater participation by students.

Nevertheless, there are also some concerns with this approach, as noted by Missildine et al. [1], including poor quality video production, the inability to provide just-in-time information when needed and the fact that the flipped approach does not necessarily mean improved levels of student satisfaction. Some students can find the inverted approach distressing at first. In our study, only a few students remained dissatisfied with the change from the traditional approach, and said that they did not want to participate or be asked questions in the classroom, despite the learning gains that this entails. Being active and participative undoubtedly requires more effort, and learning is more difficult than simply taking notes.

6. Conclusions and future work

In this study, computer simulations, virtual laboratories, interactive activities and educational videos have been applied and integrated in an online environment devised from scratch. These unconventional educational tools have facilitated self-learning, enhancing students' flexibility when choosing the place, time, and pace for learning, and allowing them to catch up if they miss a class. Furthermore, the use of these learning tools and prior self-study with them has led to the creation of more practical and participatory learning scenarios in the classroom, enabling students to deepen the content and improve their academic outcomes.

This project was undertaken with a specific subject in a real engineering domain, although similar experiences could be carried out in other subjects. The experience can be useful in encouraging other lecturers to engage in innovative activities which increase in-depth learning and improve educational outcomes. Activities of this nature can be performed for work both inside and outside the classroom.

The implications of our work are as follows: first, it is possible to develop an online learning environment with ad hoc technological tools that helps to create meaningful learning scenarios. Second, combining the virtual environment tools with the flipped classroom approach encourages student's participation and engagement. Third, these online systems and the learning methodology can have a positive impact in terms of academic outcomes and students' satisfaction.

Nevertheless, this approach does not work for all students, despite being welcomed by most of them. The previous study and the participatory learning involve more effort for students than merely listening and taking notes. This approach also involves more work for teachers, the preparation of materials and activities and to devote time for students' diversity in the classroom.

The flipped learning methodology facilitated by OLE tools has meant more work for both, students and teachers, but also it offers benefits to both. On the one hand, for students because it is obvious that the effort is rewarded by enhanced achievement. On

the other hand, for teachers because they have the opportunity to improve their teaching, to progress professionally and because of the personal satisfaction by the improvement of academic achievement or by the enrichment in the relationship with students.

Both, students and teachers are not accustomed to online learning systems and active learning methodologies of this type. Adaptation requires a change of rules, habits and customs, and even a change in the mentality of all those participating students and teachers.

Although the questionnaire was designed bearing in mind other reviewed models, the survey has some limitations in terms of the number of single response questions. In the future, a valid and reliable questionnaire needs to be designed to evaluate the impact on students' learning of the various OLE tools such as educational videos, virtual labs and game-based learning, and instructional elements such as the use of mobile devices for learning in the classroom, with analysis of both the advantages and disadvantages.

A more extensive and in-depth study would be necessary to determine the extent to which technology enables liberation from face to face traditional classroom formats to create successful approaches to establishing active learning and discussion.

The survey could also be improved by a more in-depth analysis of the students' perceptions and opinions offered in the open questions.

Furthermore, in terms of future research, it may prove interesting to evaluate how each of the resources and methodologies used on the course might impact on the learning from the point of view of the acquisition of competencies, observing the different skills that are developed or improved during the course and considering the diverse types of learners and the variety of learning styles.

References

1. K. Missildine, R. Fountain, L. Summers and K. Gosselin, Flipping the Classroom to Improve Student Performance and Satisfaction, *Journal of Nursing Education*, **52**(10), 2013, pp. 597–599.
2. P. Baepler, J. D. Walker and M. Driessen, It's not about seat time: Blending, flipping, and efficiency in active learning classrooms, *Computers & Education*, **78**, 2014, pp. 227–236.
3. J. O'Flaherty and C. Phillips, The use of flipped classrooms in higher education: A scoping review, *Internet and Higher Education*, **25**, 2015, pp. 85–95.
4. J. Enfield, Looking at the Impact of the Flipped Classroom Model of Instruction on Undergraduate Multimedia Students at CSUN, *TechTrends*, **57**(6), 2013, pp. 14–27.
5. K. S. Hurley, A case study of learner and instructor perceptions of flipped course design and interactive learning environment, *International Journal of Social Media and Interactive Learning Environments*, **2**(4), 2014, pp. 361–77.
6. B. Mull, Flipped learning: A response to five common criticisms. *November Learning.* 2012, http://novemberlearning. com/educational-resources-for-educators/teaching-and-learning-articles/flipped-learning-a-response-to-five-common-criticisms-article/, Accessed 10 February 2017.
7. S. Livingstone, Critical reflections on the benefits of ICT in education, *Oxford Review of Education*, **38**(1), 2012, pp. 9–24.
8. P. Thompson, The digital natives as learners: Technology use patterns and approaches to learning, *Computers & Education*, **65**, 2013, pp. 12–33.
9. K. Lai and K. Hong, Technology use and learning characteristics of students in higher education: Do generational differences exist?, *British Journal of Educational Technology*, **46**(4), 2015, pp. 725–738.
10. A. Ekmekci and O. Gulacar, A Case Study for Comparing the Effectiveness of a Computer Simulation and a Hands-On Activity on Learning Electric Circuits, *Eurasia Journal of Mathematics Science and Technology Education*, **11**(4), 2015, pp. 765–775.
11. M. J. Rosenberg, E-learning: *Strategies for delivering knowledge in the digital age*, McGraw-Hill, New York, 2001.
12. M. Prince, Does active learning work? A review of the research, *Journal of Engineering Education*, **93**(3), 2004, pp. 223–231.
13. A. Sams and J. Bergmann, Flip your classroom: Reach every student in every class every day, *ISTE*, 2012.
14. Horizon report, http://cdn.nmc.org/media/2015-nmc-horizon-report-HE-EN.pdf , Accessed 29 July 2016.
15. S. Freeman, S. L. Eddy, M. McDonough, M. K. Smith, N. Okoroafor, H. Jordt and M. P. Wenderoth, Active learning increases student performance in science, engineering, and mathematics, *Proceedings of the National Academy of Sciences of the United States of America*, **111**(23), 2014, pp. 8410–8415.
16. Y. Chiang, H. Wang, Effects of the In-flipped Classroom on the Learning Environment of Database Engineering, *International Journal of Engineering Education*, **31**(2), 2015, pp. 454–460.
17. D. M. Battaglia and T. Kaya, How Flipping Your First-Year Digital Circuits Course Positively Affects Student Perceptions and Learning, *International Journal of Engineering Education*, **31**(4), 2015, pp. 1126–1138.
18. M. A. Salido Gregorio, A. G. Boggino and M. A. López, Aplicación de metodologías activas en la enseñanza de informática en la licenciatura en matemáticas, *Revista Iberoamericana de Tecnologias del Aprendizaje*, **2**(2), 2007, pp. 73–78.
19. R. Toto, R. Toto and H. Nguyen, Flipping the Work Design in an industrial engineering course, 2009 *39th IEEE Frontiers in Education Conference*, 2009, pp. 1–4.
20. S. Kong, Developing information literacy and critical thinking skills through domain knowledge learning in digital classrooms: An experience of practicing flipped classroom strategy, *Computers & Education*, **78**, 2014, pp. 160–173.
21. G. S. Mason, T. R. Shuman and K. E. Cook, Comparing the Effectiveness of an Inverted Classroom to a Traditional Classroom in an Upper-Division Engineering Course, *IEEE Transactions on Education*, **56**(4), 2013, pp. 430–435.
22. M. N. Giannakos, Exploring the video-based learning research: A review of the literature, *British Journal of Educational Technology*, **44**(6), 2013, pp. E191–E195.
23. R. Kay and I. Kletskin, Evaluating the use of problem-based video podcasts to teach mathematics in higher education, *Computers & Education*, **59**(2), 2012, pp. 619–627.
24. J. Wells, R. M. Barry and A. Spence, Using Video Tutorials as a Carrot-and-Stick Approach to Learning, *IEEE Transactions on Education*, **25**(4), 2012, pp. 453–458.
25. F. Donkor, The Comparative Instructional Effectiveness of Print-Based and Video-Based Instructional Materials for Teaching Practical Skills at a Distance, *International Review of Research in Open and Distance Learning*, **11**(1), 2010, pp. 96–115.
26. T. Seidel, G. Blomberg and A. Renkl, Instructional strategies for using video in teacher education, *Teaching and Teacher Education*, **34**, 2013, pp. 56–65.
27. G. Blomberg, M. G. Sherin, A. Renkl, I. Glogger and T. Seidel, Understanding video as a tool for teacher education:

investigating instructional strategies to promote reflection, *Instructional Science*, **42**(3), 2014, pp. 443–463.
28. T. Sheorey, Empirical Evidence of Relationship between Virtual Lab Development and Students Learning through Field Trials on Vlab on Mechatronics, *International Journal of Information and Education Technology*, **4**(1), 2014, pp. 97–102.
29. S. M. Harb, A. Harb and I. Batarseh, Development, implementation, assessment of a web-based circuit solver for teaching basic electrical circuits theory, *International Journal of Online Engineering*, **11**(4), 2015, pp. 55–61.
30. E. T. Chu and C. Fang, CALEE: A computer-assisted learning system for embedded OS laboratory exercises, *Computers & Education*, **84**, 2015, pp. 36–48.
31. R. Sell and S. Seiler, Improvements of multi-disciplinary engineering study by exploiting design-centric approach, supported by remote and virtual labs, *International Journal of Engineering Education*, **28**(4), 2012, pp. 759–766.
32. M. K. S. Sastry and R. Ali, The design and development of a virtual laboratory for power system modelling and load flow analysis to promote innovative learning, *International Journal of Innovation and Learning*, **6**(2), 2009, pp. 178–191.
33. R. Weiss, D. Knowlton and G. Morrison, Principles for using animation in computer-based instruction: theoretical heuristics for effective design, *Computers in Human Behavior*, **18**(4), 2002, pp. 465–477.
34. M. Filsecker and D. T. Hickey, A multilevel analysis of the effects of external rewards on elementary students' motivation, engagement and learning in an educational game, *Computers & Education*, **75**, 2014, pp. 136–148.
35. T. Auvinen, L. Hakulinen and L. Malmi, Increasing Students' Awareness of Their Behavior in Online Learning Environments with Visualizations and Achievement Badges, *IEEE Transactions on Learning Technologies*, **8**(3), 2015, pp. 261–273.
36. I. V. Osipov, E. Nikulchev, A. A. Volinsky and A. Y. Prasikova, Study of Gamification Effectiveness in Online e-Learning Systems, *International Journal of Advanced Computer Science and Applications*, **6**(2), 2015, pp. 71–77.
37. A. Dominguez, J. Saenz-de-Navarrete, L. de-Marcos, L. Fernandez-Sanz, C. Pages and J. Martinez-Herraiz, Gamifying learning experiences: Practical implications and outcomes, *Computers & Education*, **63**, 2013, pp. 380–392.
38. G. Hwang, P. Wu and C. Chen, An online game approach for improving students' learning performance in web-based problem-solving activities, *Computers & Education*, **59**(4), 2012, pp. 1246–1256.
39. M. Ibanez, A. Di-Serio and C. Delgado-Kloos, Gamification for Engaging Computer Science Students in Learning Activities: A Case Study, *Ieee Transactions on Learning Technologies*, **7**(3), 2014, pp. 291–301.
40. M. Victoria Lopez-Perez, M. Carmen Perez-Lopez and L. Rodriguez-Ariza, Blended learning in higher education: Students' perceptions and their relation to outcomes, *Computers & Education*, **56**(3), 2011, pp. 818–826.
41. I. Cohen, N. Sebe, A. Garg, L. S. Chen and T. S. Huang, Facial expression recognition from video sequences: temporal and static modeling, *Computer Vision and Image Understanding*, **91**(1), 2003, pp. 160–187.
42. J. Riegelsberger, The effect of facial cues on trust in e-commerce systems, *Proceedings of HCI*, 2002.
43. Kahoot, https://getkahoot.com/, Accessed 29 July 2016.
44. Socrative, http://www.socrative.com/, Accessed 29 July 2016.
45. P. P. G. Abenza, P. P. G. Abenza, A. G. Olivo and B. L. Latorre, VisualJVM: A Visual Tool for Teaching Java Technology, *IEEE Transactions on Education*, **51**(1), 2008, pp. 86–92.
46. R-Project org, https://www.r-project.org/, Accessed 29 July 2016.
47. D. W. Straub, Validating Instruments in MIS Research, *MIS Quarterly*, **13**(2), 1989, pp. 147–169.
48. D. Straub, M. Boudreau and D. Gefen, Validation Guidelines for IS Positivist Research, *Communications of the Association for Information Systems*, **13**(1), 2004.
49. K. McMath, The use of Response Technology in Enhancing Motivation, Participation and Retention of Material in University Students in Addition to Other Pedagogical Benefits, *Iceri2015: 8th International Conference of Education, Research and Innovation*, 2015, pp. 70–70.

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