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Web-based OERs in Computer Networks (manuscript draft)

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Pablo Gil, Francisco A. Candelas, Carlos A. Jara, Gabriel. J. García, Fernando Torres
Department of Physics, System Engineering and Signal Theory. University of Alicante.
San Vicente del Raspeig, Spain.
E-mails: pablo.gil@ua.es, francisco.candelas@ua.es

Abstract

Learning and teaching processes are continually changing. Therefore, design of learning technologies has gained interest in educators and educational institutions from secondary school to higher education. This paper describes the successfully use in education of social learning technologies and virtual laboratories designed by the authors, as well as videos developed by the students. These tools, combined with other open educational resources based on a blended-learning methodology, have been employed to teach the subject of Computer Networks. We have verified not only that the application of OERs into the learning process leads to a significantly improvement of the assessments, but also that the combination of several OERs enhances their effectiveness. These results are supported by, firstly, a study of both students' opinion and students' behaviour over five academic years, and, secondly, a correlation analysis between the use of OERs and the grades obtained by students.

Keywords: educational technologies; computer science education; computer networks; virtual laboratories; e-learning

1. Introduction

Blended learning is defined as the integration of traditional classroom methods with online activities in order to complement face-to-face classes with e-learning resources [1]. In recent years, this educational method is being usually applied to adapt the contents and methodologies of the matters to the ESHE [2,3], which determines that traditional education must be combined with a good distance education in order to provide flexibility to students. In this new educational context, the Open Educational Resources (OERs) [4] play an important role, because they are designed for a distance self-learning. The work presented in this paper shows the successful application of a blended-learning methodology in the subject of Computer Networks coursed in the Computer Science Engineering degree at the University of Alicante, in Spain. These OERs are used in order to provide students a way to configure their own free schedule according to their necessity and their level of knowledge.

As many authors consider [5-7], a successfully Computer Networks teaching is often a hard task, mainly because students tend not to maintain acceptable levels of motivation. Computer networking concepts cover many details about protocols and configuration techniques, and thus both a right education methodology and proper resources are needed to enhance student learning. Several research studies have been carried out in order to overcome this problem and to help students obtain a deeper understanding of computer networks. Most of them adopted only a hands-on learning strategy providing students with practical exercises with hardware devices in a Local Area Network (LAN) [6] in order to build high-performance networking systems [8]. Other

approaches have used only simulators as software resources for the subject [9] or as supplementary teaching tools [10].

In this paper, the authors have used a blended-learning method, where face-to-face hands-on experiments in a real laboratory are supported with new educational technologies for e-learning. Specifically, the Learning Content Management System (LCMS) Moodle [11] is combined with digital resources based on the Web2.0 such as OpenCourseWare (OCW) [12] and Blogs [13]. These tools are also supplemented with open-source simulation tools designed by the authors and with videos developed by the students.

The paper is organised as follows: Section 2 explains the blended-learning methodology, showing aspects such as its organisation and evaluation. The development of the digital resources is shown in Section 3. Section 4 describes the simulation applets developed to teach and learn Computer Networks. Section 5 explains the results of questionnaires proposed to students in order to know their opinion about the methodology and to assess the approach's efficiency. In addition, a statistical study to find relationships among OERs and grades achieved by students is presented. Finally, important conclusions are reported in Section 6.

2. Educational methodology

From 2007 to 2012, the authors have designed five Computer Networks courses that consist of 1 regular lecture (2 hours per week) and 1 regular practical lesson in a lab (3 hours per week). Details about the courses can be observed in Table 1. The average age of students was 21-22 years old. In these years, OERs have been a key issue in supporting students' learning in order to adapt this to ESHE.

Computer Networks is a subject that covers different aspects of the computer networking, such as network architectures, current technologies and systems for present-day data communications, protocols and devices for data transmission or software tools to manage computer networks.

Since the 2008 academic year, Moodle has been used to manage different elements involved in student learning of Computer Networks. During the last years, a Moodle course has been employed in the experimental part of the subject. In contrast to classical assessment methodology based on paper exams, the new methodology implemented allows quantifying the amount of knowledge acquired by the student and the quality of learning from a system of evaluation and self-correction based on the Moodle's quiz module.

Academic years	2007/2008	2008/2009	2009/2010	2010/2011	2011/2012
Student degree (level)	3	3	3	3	3
Subjects	1	1	1	1	2
N. of practical hours (P)	45	45	45	45	45
N. hours of theory (T)	30	30	30	30	30
N. of students	140	115	94	83	69
N. of lectures T	1	2	2	2	1
N. of lectures P	1	3	3	2	3
N. of students that pass	54	58	24	34	25

Table 1. General data for courses according to academic years

The lectures are based on a set of slides that allows the teacher to explain the concepts of each topic. These slides are provided to students as resources shared in the Moodle course. During the class, the teacher

explains in detail the various items included in the slides and performs exercises and problems that allow consolidating the concepts explained.

The evaluation of the experimental part of the subject has been automated by the quiz module of Moodle. It is performed by four quizzes which consist of short multiple choice questions, short answer questions and/or short exercises. The new evaluation methodology requires providing to the system with a tool that allows students to mitigate the problems of understanding and fear of the unknown. A system of self-assessment, built by using Wimba Create [14] and embedded in the report of the practice, has been developed to solve this problem. These self-assessment tests are very similar to the evaluation tests, but the marks obtained by the students are only considered by themselves to verify that they understand and know the most important contents. In this way, students can detect learning problems while reducing the fear of the assessment review.

The evaluation of the theoretical concepts is performed continuously by means of delivering questionnaires, exercises and problems during the course. The final exam consists of two parts: a set of questions and multiple choice questions, and problems based on the contents presented in the lectures.

3. Development of the digital resources

During the last academic years, five different types of digital resources have been developed and different studies have been performed about their use by the student. Besides educational platforms, such as Moodle [11], other types of resources have been designed and implemented as supplement: OpenCourseWare (OCW) [12], Blogs [13], Videos [15] and interactive simulations [16]. Nowadays, especially from ESHE, these tools establish an emerging new education approach that enhances learning experiences by integrating multimedia and e-learning resources [17].

3.1 OpenCourseWare

In April 2001, MIT announced the OpenCourseWare project [18]. MIT defined an OCW as course materials that are used in the teaching of almost all undergraduate and graduate subjects available on the web, free of charge, to any user anywhere in the world. It is important to remark that the educational material of an OCW must be obtained from existing classroom courses and not for a specially developed e-learning environment.

In the authors' opinion, a courseware should be developed as a part integrated in courses which consist of a mix multimedia of materials (such as textbooks, videos, software, links and interactive simulations). This fact is becoming increasingly important because the students have become more demanding and fussy. They are not satisfied only with electronic resources of lectures with additional support. Students request more interactive content in an OCW because the slides and files of the subject contents are hard to understand without a context of the course. Our OCW [19] has been created as an interactive web repository which stores OERs. These OERs are composed by multimedia videos, electronic documents, interactive simulations and several external links to provide more information to the students.

The OCW proposed [20] has been organised following the next structure: presentation, aims and scope, contents, educational methodology, evaluation, educational resources, bibliography and the Internet resources. The educational contents, the implemented resources as well as the tools to provide feedback to the students have allowed us to accomplish with three key aspects proposed in [21] to ensure the quality required in an OCW.

They are the course information, the learning guide (tutorial) and the evaluation and/or self-evaluation with feedback to the students.

The presentation consists of two videos created by teachers about the practical and theoretical contents as well as aims, methodology, assessment and resources of the Computer Network subjects. The videos show several slides in addition to the audio comments and the image of the teacher with the explanations. The aims, the contents and the educational methodology are handled as simple static web pages, so that when the students select a choice, the web page appears instantly. The resources section shows all the textbooks and documents created and used by the teachers. They are provided in digital formats by means of links from the Repository of the University of Alicante (RUA) [22] where they have been previously stored. Finally, in the Internet resources section, several web links are available for accessing to interactive simulations applets [16, 23]. This type of resources will be commented in the next section.

In general, the OCW is very useful because it allows students to engage in their self-learning study, providing on-line resources available outside the classroom or laboratory, which are not face-to-face. Additionally, the OCW can be used by other teachers from other universities in order to follow the educational contents and methodology used in similar subjects about Computer Networks.

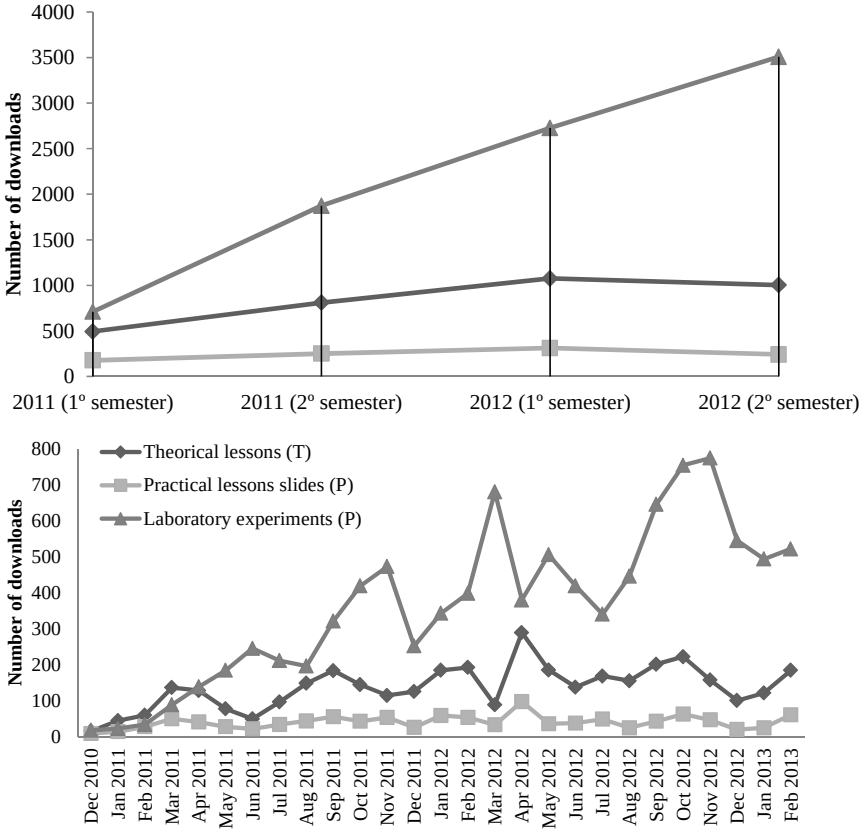

Fig. 1. Evolution of number of downloads by semesters and months from presented OCW

Reference [12] shows how MIT has integrated an evaluation program that probes three aspects: what student profile has user who access OCW, how students and teacher use this resource and what impact on the educational processes is generated. In terms of access, the presented OCW and theirs materials are accessible since December 2010. Until today (February 2013), more than 3,701 and 10,576 users have downloaded materials about theoretical and practical classes, respectively (Fig 1). The OCW visitors come mainly from Spain

(41.4% and 32.5%), Latin America (51.2% and 60.1%), and North America (3.8% and 2.9%), countries where there are Spanish speaking communities. Recently, the educational resources are also being accessed from other geographical areas (2.2% and 3.4%), such as Europe, Asia and Africa, with a similar percentage. The received visits and downloads have been 1.4% and 1.1% from local university. These downloads correspond to their students. However, the profile of these users is unknown. The information about whether they are self-learners, students or educators is not available. Table 2 shows the download information classified by years and type of materials.

In terms of impact, it is significant the fact that the University of Alicante (UA) won the award of OCW-Consortium 'Landmark Site' for excellence this last year, 2011.

Countries/Academic years	2011(P)	2011(T)	2012(P)	2012(T)
University of Alicante	2.7%	2.2%	0.6%	1.2%
Spain	36.5%	55.6%	30.3%	32.5%
Latin-America	54.9%	37.3%	62.7%	59.8%
North-America	3.6%	3.1%	2.6%	4.4%
Others	2.3%	1.8%	3.8%	2.1%
TOTAL*	3010	1303	6787	2078

(P) This value is referred to practical lessons and laboratory documents. (T)This value is referred to theoretical lesson and lectures. (*) This value is referred to the total number of downloads

Table 2. Access and download rates for the OCW resources

3.2 Blog

The blogs, in an educational context, have been gaining popularity in the last years. A basic blog can be defined as a collection of entries displayed on a web page. These entries are shown in reverse chronological order and they are frequently updated. Mainly, blogs were created as a tool to enhance the communication between learners (readers) and teachers (bloggers) in educational contexts [13]. In addition, one of the most important features of blogs is that they are not geographically or temporally constrained [24]. Unlike [25], this paper is focused on determining the influence of spreading information for student learning on blogs. At present, there is not a standardised blog template for educational contexts. For this reason, the authors have proposed a template similar to the OCW.

In the proposed blog [26], there are posts about aspects of the subject such as the following: content and objectives, program, bibliography, links to educational resources (free-open software, simulations, videos, etc.), links and information about other courses of Computer Networks, and relevant news related to the subject. Related news such as new communication technologies and systems are commented, courses about computer networks offered in Spanish universities and private companies have been added to motivate the students to complete their training. Web links about OCW from other universities and institutions have been added to gain the student's attention while teachers increase the students learning possibilities.

There are several reasons that pushed the authors to adopt an own education blog. They are commented in [19]: perceived enjoyment, codification effort, compatibility, perceived ease of use, personal innovativeness, enjoyment in helping others, school support and perceived usefulness. But also, the blogs allow a different group of students to achieve communication and content production (i.e. the blog provides feedback to OCW).

The union of the OCW and the blog provides the possibility to locate and supply material resources for learning and, thus, it helps students to find relevant content with relation to the theoretical classes. In addition, e-

learning tools like this one can increase the participation and the collaborative relationships between students, since they can share experiences or opinions during the lectures.

Visit duration	Visits	Pageviews	Count Visits	Frequency	Recentness
<1min	86.1%	63.3%	**1**	86.3%	81.4%
1-3min	5.2%	10.5%	**2**	7.3%	8.3%
2-10min	5.1%	13.3%	**3**	2%	3.2%
>10min	3.6%	13%	**>=3**	4.4%	7.1%

Table 3. Behaviour of blog readers obtained from Google Analytics, from February 2012 until February 2013

Contents	Average Time on page (min.)	Bounce Rate (%)	Exit (%)
Didactical general resources			
Software Wi-Fi	4.07	89.2	86.0
CISCO courses	4.06	81.1	73.6
Open free simulators	3.27	80.4	77.0
Not-free simulators	2.49	78.5	72.6
Section of blogs			
Practical content (included videos)	3.02	71.8	58.2
Objectives of subject	2.49	89.2	86.0
Didactical general resources	2.05	70.2	56.6
Principal page (included general posts)	1.57	58.6	53.2
New Posts of subject	1.46	54.2	48.0
Bibliography of subject	1.42	85.4	64.7
Professor information	1.19	65.7	36.0
Theoretical content of subject	1.10	79.9	33.3
Textbook/References of subject	0.55	77.4	39.0
Blog general information	0.40	24.0	18.3

Table 4. Most popular contents of the blog from Google Analytics, from February 2012 until February 2013

This blog is accessible since June 2010. Until today (February 2013), 83 and 262 students from University of Alicante that are enrolled in the subject of Computer Networks have accessed to the blog in these two last academic years. Furthermore, from February 2011, the visit statistics is done by means of the Google Analytics tool (Tables 3 and 4). This tool allows knowing the location and language of visitors from outside of University of Alicante. The origin of visitors has determined that they come mainly from Spain (21%), Latin America (56.6%), and North America (0.8%), countries where there is Spanish speaking community. The rest, 21.5% access from other geographical areas. The 13.7% (2,032 visits) are returning visitors vs. 86.3% (12,829 visits) which are new. Before February 2011, statistics have only been done available to visitors from inside University of Alicante (see the Section 5). In addition, three aspects about behaviour of visitors have been measured. They are: the frequency and the recentness (Table 3), what pages are the most frequently accessed or how much time is spent by the visitors (Table 4).

On the one hand, the bounce rate is the percentage of single-page visits or those visits in which the person left the site from the entrance (landing) page. These visitors have not acceded to other pages of blog. Sometimes, the bounce rate is high because the visitors have found what they were finding. Therefore, they do

not need to keep browsing the blog. On the other hand, the average time on page is the ratio between the total time of visits and the number of visits.

In terms of impact, this blog about Computer Networks was voted as the best blog of University of Alicante in 2011. It was awarded due to its quality of learning resources, structure, organisation and contents.

3.3 Video logs

The development of multimedia technologies, the Internet and the automatic capture to create presentation [27] and video lectures [15,28] are becoming very popular, especially in distance learning. Keeping in mind that the direct support of the teacher is not available for the student when he/she studies on their own outside the classroom or laboratory, it was decided to include video logs as new online resource in order to facilitate the understanding about concepts on protocols working. When the videos have been produced, they are encoded, tagged and published in different places such as UAVideoTube (The YouTube channel for University of Alicante) [29] and RUA [21].

Each video log has been created as short documentary video, describing the development, step by step, of a lab experience in which the working of a specific communication protocol is analysed. In most video logs, the experience is described in the same way that it should be carried out in the laboratory of the faculty, using the same hardware equipment and networking software [30]. In other video logs, concepts are explained by using the network simulator KivaNS [31, 32] (see Section 4).

Teachers always review the videos produced by students to select those that are properly explained and better described. Afterwards, a collection of selected videos are published as open online resources on the blog of the subject.

4. Design of the interactive simulations

Currently, there are several free applications for simulating computer networks and TCP/IP routing. Nevertheless, most of them have user interfaces based on programming languages so that they are not quite intuitive for students. This is the case of “J-Sim Network Simulator” [34], “NS” (Network Simulator) [34] and “Partov Simulation Engine” [7] in which the programming is required to prepare the simulation and get the results. The “cnet network simulator” is another interesting free option [35] which simulates different network layers and technologies. However, “cnet” is mainly focused in evaluating the performance of data transmissions and it can only be executed on Linux or Unix systems. Another software such as “TCP Flow Control Simulation and Visualization” [36] is a good example of simulation program but only for the specific Transmission Control Protocol of the TCP/IP architecture. Another tool is Gns (Graphical Network Simulator) [37] which is used to experiment features of routers and check configurations that need to be deployed later on real routers but it requires the operative system of the real routers to be simulated.

In general, space, cost and security are reasons to build software applications to simulate the behaviour of LANs. In addition, the virtual laboratories allow the students learn at their own way. In general, the good learning with virtual laboratories and simulators must be accompanied of guided experiments in form of courses as is commented in [38].

The proposed approach is based on interactive and portable Java applets developed from KivaNS [31] and Easy Java Simulations [39]. These applets do not require any kind of programming to simulate the protocols

of the TCP/IP architecture and they have a very user-friendly interface. In this research line, other recent work is the presented in [40].

4.1 KivaNS

KivaNS [32] is a free and open source software application designed in Java language to simulate and study how IP (Internet Protocol) works. In order to do this, KivaNS also includes the simulation of auxiliary protocols such as ARP (Address Resolution Protocol), and ICMP (Internet Control Message Protocol), in addition to IP, and emulates the basic working of link layer technologies such as PPP (Point to Point Protocol), Ethernet or switched Ethernet.

KivaNS is composed of two main modules. The first module is an API (Application Programming Interface) that offers a simulation engine for data networks. The second module is a complete graphical user interface. Fig. 2a shows the layout of the user interface.

The result of a simulation is mainly a trace of all the events generated and processed by the different objects. This trace includes the packets of selected protocols, in a similar way to the trace given by a protocol analyser-sniffer in a real network. It is also possible to simulate different kinds of errors in the networks and equipment, such as packets loss and bad routing tables. Errors detected by protocols, such as timeouts or checksums, are also recorded in the trace.

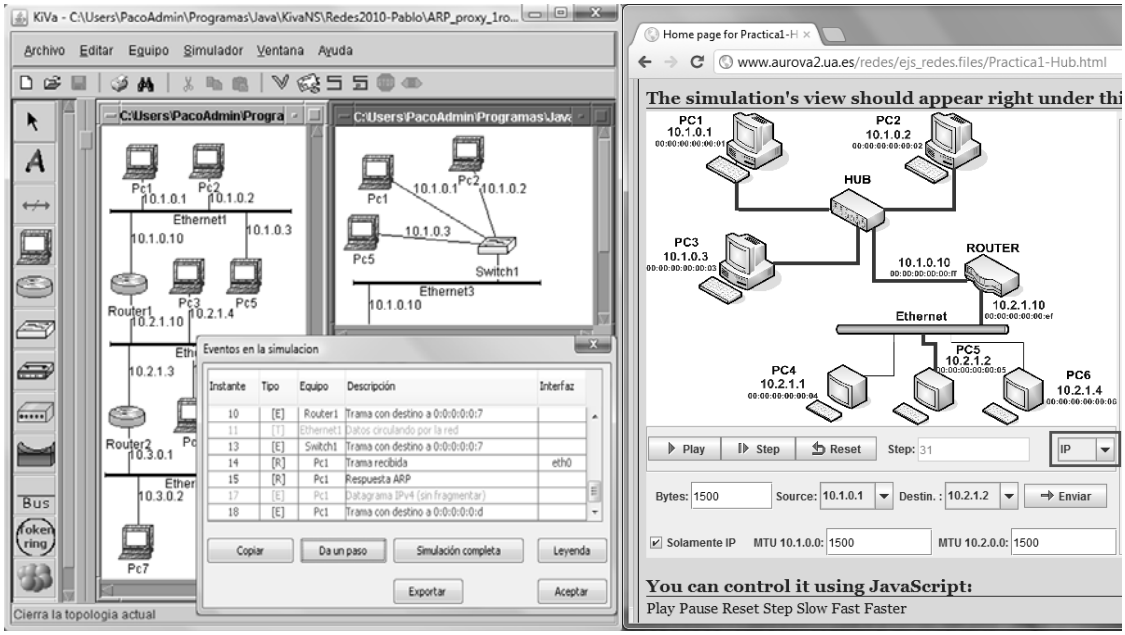

Fig. 2. a) User interface of KivaNS application. b) Applet user interface for simulating data transmission in an Ethernet LAN

4.2 Applets using EJS

KivaNS has been designed as a stand-alone application. Thus, it cannot be included in a web page, blog or LCMS, and it is not suitable to quickly teach specific simulations about aspects about working of networks. For this reason, authors have combined the use of the software EJS [41], with the simulation engine of KivaNS. EJS is an open-source tool developed for the creation of interactive simulations, in the form of Java-applets (see Fig. 2b) that can easily be embedded in a web page or even in LCMS like Moodle. The interface of EJS allows users to develop simulations in an easy and quickly way. In addition, EJS is able to use external libraries of code

and this feature has been used to include the KivaNS API in projects of EJS. The result is a set of Java applets for simulating specific situations of the networks working, which are easily embedded into web pages [32].The simulations offered by these applets allow students to explore cases such as the following:

- Operation of ARP.
- Functioning of bus or switched in Ethernet networks.
- Differences in the functionality among network devices.
- Working of IP, even considering fragmentation of data.
- IP addressing and broadcasting.
- Routing of IP datagrams through one or more routers.
- Commonly used ICMP messages.

5. Results and discussion

5.1 Student's opinion

A survey and interview were arranged to measure student satisfaction in relation to resources used in the Computer Networks' courses. The results show a positive correlation between type and number of educational resources and the student learning. In general, the conclusion is that the joint use of these resources, as in the aforesaid learning integral system, is very beneficial for the educational process of student in engineering. There are already many teachers who are using these tools in their teaching but an isolated way, without combining with other tools.

The surveys performed to students after last academic year (2011/2012) have given the opportunity to collect information about habits, level of agree, frequency of use, etc. related to how students use the resources, as shown in Table 5.

N. Accesses	Blog	OCW	N. hours	Other resources (Internet)
Never	6.8%	33.3%	**Never**	8.5%
1 time/week	52.3%	46.7%	**0-1hours**	29.8%
2 times/week	36.4%	11.1%	**1-5hours**	46.8%
2-4 times/week	4.5%	8.9%	**5-10hours**	8.5%
>4 times/week	0%	0%	**>10hours**	6.4%

Table 5. Student behaviour at University of Alicante obtained from a survey in classroom

On the one hand, the students compared the blog 'Computer Networks' with other blogs at the University of Alicante by means of survey carried out in the classroom. This result is shown in Fig. 3a. This comparison was done from a viewpoint of handling (ease to use), organisation (how the contents were structured and if they were easy to find), update frequency and the relevance of own and foreign links and resources. The scale of qualification is from 1 (totally disagree and/or dissatisfied) to 5 (totally agree and/or satisfied).

As it can be seen in this figure, the most of the students thought that the 'Computer Networks blog' is better than other educational blogs known by them. The students highlight the blog structure and the linked resources. Also, Fig. 3 shows a statistical analysis of the distributions, and the value which occurs most frequently in each data set (statistic value of mode) is 4 for own resources and organisation of blog, and 3 for the updating, the handling and foreign resources linked from blog. In addition, the average value is always equal or bigger than 3 for all aspects. In particular, it is 4 in regard to the relevance of resources developed of authors and commented in Sections 3 and 4.

On the other hand, the students were asked about if the learning process is improved by using blogs and OCW and the degree of improvement. According to the opinion about blogs, 78.3% (equal or bigger than a score of 3) of students thought that learning was more fun. The score 3 was the value more repeated by students when they gave their opinion about the additional information published in the blog, such as news of the computer network world, information about courses taught in other universities and institutions, etc. (67.3% of students voted 3 or higher). However, the students considered (they voted 4 in the great majority and 78.2% vote 3 or higher) that the digital resources provided (on-line courses, videos, links to simulators and software) and the communications between students and other people interested in the topic of computer networks become more fluid (71.7% of students). They thought that the comments about information of blog could greatly enhance and help the communications among students of different universities or the same university.

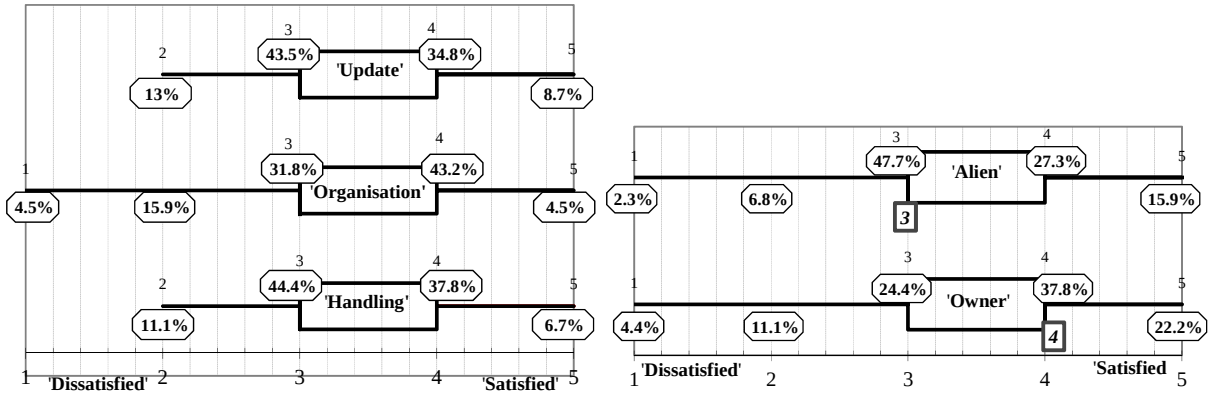

Fig. 3. Student's opinion about: a) the blog in relation to the blogs of other subjects at University of Alicante. b) Relevance of resources provides from the blog

According to the opinion about OCW, the results of the research were the followings: 80.8% of students thought that an OCW could replace the teaching methodology based on masterly lessons (40.4% voted 4 and 40.4% voted 3).

The great majority of students thought that OCW improves the autonomous learning process. Almost 47% voted 4, 20% voted 5 and only 19% thought the opposite (voted 1 or 2). In general, the students were interested in the development of computer-based courseware although the number of these students was lower than those students who considered useful the OCW in combination with masterly lesson. In this way, many students thought that they could be interested only when a distance self-learning methodology is required (53.4% voted below 2 and only 13.3% voted 4 or higher).

In Section 4, the Tables 2, 3 and 4 show information about accesses and behaviour of learners who acceded to the created resources (blog, OCW) to read or download materials. The study presented (Fig. 5) shows which sections of these resources were the most or less visited by the students. The results show that the video logs and slides, acceded from a link to OCW, are on the top rate of the resources published from the blog. Other important resources which were accessed very often are the news and the detail of the program of practical and theoretical classes. The sections with fewer hits were the teacher information and objectives of subject.

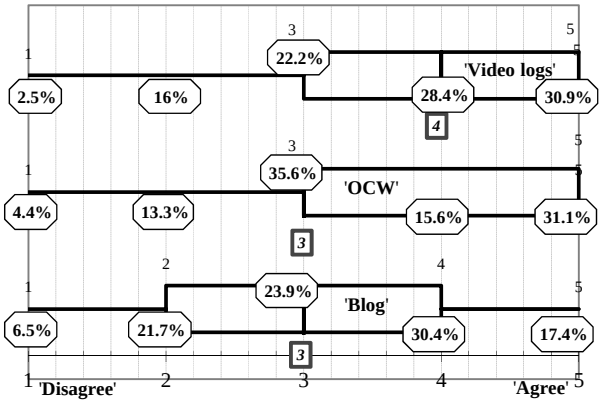

Fig. 4. Comparison of educational tools: Goodness level of these tools to enhance learning in face to face methodology (data obtained from a survey in classroom)

Furthermore, the students gave their view on video logs. The students were asked about what topics are easier to understand when they watched the videos. 65.1% and 55.8% thought that they had now a better understanding of ARP and ICMP protocols, respectively. In these cases, the students voted 4 or more when they were asked (5 is totally agree). The same way, 46.9% and 73.4% of them thought that the comprehension of addressing and routing have improved after watching the videos. In addition, the teachers wanted to know if the videos were useful for distance education and classroom education. That is, the degree to which they could replace the teacher's explanations. In general, the 73% of students gave an affirmative answer when they were asked about this (they voted 4 or higher).

Finally, the students were asked if the teaching/learning model supplemented with these tools was better than teaching/learning without them. Here, the teacher wanted to know if the students considered these educational resources (blogs, OCW and video logs) essential tools to learn Computer Networks subject in face to face educational methodology. Interpreting the results shown in Fig. 5, 81.5%, 82.3% and 71.7% voted 3 or higher in a scale between 1 and 5.

5.2 Analysis: Interpretation of correlations

In this subsection, a statistic analysis based on interpretation of correlations is presented in order to evaluate the influence in the students' grades when the OERs are used or not in the learning process. Therefore, authors provide triangulated data to confirm the main findings of this paper: the influence of OERs in the learning process. Thus, the initial hypothesis or null hypothesis, H_0, is to assert that the grade achieved from the assessment tests is not better if more OERs are used in the learning process. The alternative hypothesis, H_1, is true when H_0 is rejected. Therefore, H_1 is true when the grade achieved depends on the number of OERs.

The study has been made from the analysis of the grades of students organised in a histogram. The histogram is obtained by splitting the range of data into bins, called classes. These bins are represented by the score tables for the grades according to Spanish Academic Grading System (Table 6). The statistical sample has a size of 501 students. Those are the students who have coursed Computer Networks from 2007 until today. In addition, it is known that 140 students have never used OERs and the rest, 361 students have used one or more OERs (Table 1). Furthermore, the analysis has been made by normalisation of the data for all samples. Thereby, the number of data is the same for each sample so they can be compared now. This normalisation was required

because the number of students/course was different each year (i.e. 115 students used one OER in 2008 and 69 students used five different OERs in 2012).

Percentages* Hits/Faults	Spain [0-10]	USA GPA [0-4]	Year 2007/2008	Year 2008/2009	Year 2009/2010	Year 2010/2011	Year 2011/2012
90-100%	Excellent (A,A+)	A (3.6-4]	3.1%	1%	1.1%	1.4%	2%
80-89%	Very good (B+,A-)	B (3.2-3.6]	8.3%	10%	14.8%	11.1%	22%
70-79%	Very good (B-, B)	C (2.8-3.2]	25.5%	21%	26.1%	30.6%	38%
60-69%	Good (C-,C,C+)	D (2.4-2.8]	28.6%	32%	27.3%	36.1%	26%
50-59%	Sufficient (D)	E [2-2.4]	28.6%	24%	18.2%	15.3%	10%
<50%	Failure (E,F)	F [0-2)	6.1%	12%	12.5%	5.6%	2%
Student dropout rate			27.90%	14.5%	7.4%	12.2%	2.6%

*Equivalence approximated among grades Spanish and USA Academic Grading Systems

Table 6. Grade acquired by our students from 2008 until 2012

During the five last academic years, in the period from September 2007 to July 2012, new OERs have been implemented to measure the learners' interest and the improvement of the grades achieved by students when these tools are included as part of the teaching methodology (Table 7). Up to 5 new OERs have been used by students in the last year such as simulators, blogs, OCW, videos, etc. The study searches the relationship between the number of educational digital resources and the achieved grades (Table 8).

Resources/Academic years	2007/2008	2008/2009	2009/2010	2010/2011	2011/2012
LCMS-Moodle (Lessons in SCORM packets and Quiz)	NO	YES	YES	YES	YES
Network simulator (KivaNS)	NO	NO	YES	YES	YES
Applets of simulation (from KivaNS+EJS)	NO	NO	NO	YES	YES
OCW and blog	NO	NO	NO	YES	YES
Video logs	NO	NO	NO	NO	YES
N. of resources (x)	**0**	**1**	**2**	**4**	**5**

Table 7. Educational resources used in each academic year

Table 8 summarises the correlation tests of the relation between number of OERs used from academic years, *x*, and achieved grades, *y*. The content of each academic year was very similar but one or more new educational resources were added keeping those were used in previous academic years. Those can be viewed in Table 7. Three unilateral and bilateral tests have been done to find the correlation between the two variables, *x* and y_i where i=1...3.

Considering Pearson's test [42, 43], the correlation coefficient, r_p, is greater than 0.7. Pearson's test requires a strong correlation, and if this value is less than 0.3 the correlation is small, while values between 0.3 and 0.7 indicate a medium or neutral correlation. In addition, the study of the t-student for these two independent samples, *x* and y_1, shows that 2.47<2.77 (t-statistic<t-critical value) and 0.06>0.05 (p-value of two tail>alpha value critical). Then 2.77 is the t-value that we would need to exceed so that the difference between the means of the two variables could be significant (5% level). In this case, both means have no significant variation.

		Pearson's and Spearman' Correlation				
Variable Concept	*Variable Label*	*Corr. Factor r_p*	*Corr. Factor r_s*	*t-student*	*p-value two tail*	*t-critical value*
N. of students who achieved a high grade (>=80%)	$\mathbf{y_1}$	0.74182	0.8	2.47415	0.06866	2.77644
N. of students who passed the exams (>=50%)	$\mathbf{y_2}$	0.58463	0.6	1.61171	0.18231	2.77644
N. of students who dropped out the course	$\mathbf{y_3}$	-0.80765	-0.9	2.36009	0.07765	2.77644

Table 8. Relationships between academic grades and number of resources used for each academic year

The initial hypothesis for t-student is to check if the standard deviation can be assumed equal and the distribution is normal or quasi-normal. Moreover, from Pearson's test, the coefficient of determination can be computed as the square of the sample correlation coefficient, ($r_p^2=0.7418^2=0.5503$). This factor estimates the fraction of the variance in grades, *y*, that is explained by the number of resources, *x*, in a simple linear regression. Hence, 55.03% of variability in the high grades obtained by students is due to the number of resources (over 80% success, better than or equal to B+).

Following the same dissertation, for the two independent samples, *x* and y_2, the t-student distribution shows that 1.61<2.77 (t-statistic<t-critical value) and 0.1823>0.05. In addition, Pearson's correlation factor is $r_p=0.58463$ and $r_p^2=0.3418$ (34.18%). In this case, the correlation is medium. We have not asserted that the increment of students who pass the subject (grade >=E) is greater because they have used OERs. Likewise, 65.23% of variability in the low level for the dropout rate by students is due to the increment of the OERs employed by students in the subject, y_3 ($r_p^2=0.6523$ where $r_p=-0.8076$). The t-student in this case shows that 2.36<2.77 (t-statistic<t-critical value) and 0.007>0.05 (p-value of two tail>alpha value critical).

Considering Spearman's test [43], similar conclusions can be obtained. Thus, for the three previous cases identified by the variables, y_1, y_2 and y_3, the correlation coefficient, r_s have been computed. The results are 0.8, 0.6 and -0.9, respectively. Therefore, the number of OERs explains the improvement of grades in the different academic courses when new resources are used to support the learning process. There is a positive correlation between the number of OERs and the grade achieved to the students. This information is shown in table 8. The advantage of Spearman correlation versus Pearson correlation is that it gives better correlations between variables even if their relationship is not linear. Nevertheless, if there are not strong outliers both correlations are similar. Spearman correlation is less sensitive than Pearson correlation to strong outliers that are in the tails of both samples.

5.3 Analysis: Linear regression

In the previous section, it was shown that there is a relationship between the improvement of high assessment grade achieved by students and how they have used OERs to support their learning. Now, a regression lineal test is used to check again if the linearity is presented in this relationship.

Table 9 shows that range of assessment grades, from groups of data obtained by splitting the range of grade achieved by students, are more dependent OERs. The initial hypothesis is to assume the linear dependence on the grades y_i and the number of resources, *x*, where *i* denote the class or range of assessment grades. Then,

this relationship can be denoted as $y_i=\beta_{0i}+\beta_{1i}x$ where the values β_{0i} and β_{1i} are the slope and the y-coordinate where the line intersects the y-axis.

	Least squares regression analysis							
Variable Concept	β_{oi}	β_{1i}	*Mult. Corr. Coef*	*Det. Coef* R^2	*Correct* R^2	*Stand. Error*	*F*	*Critical value F*
$y_1=\beta_{01}+\beta_{11}x$	0.10316	0.01934	0.74182	0.55031	0.40041	0.04188	3.6712	0.1512
$y_2=\beta_{02}+\beta_{12}x$	0.89355	0.01276	0.58463	0.34180	0.12240	0.04242	1.5578	0.3005
$y_3=\beta_{03}+\beta_{13}x$	4.67322	-17.4863	0.80663	0.65065	0.53420	0.06528	5.5874	0.0990

Table 9. Linear relationships between academic grades and number of resources used for each academic year

On the one hand, the fit of linear regression is closely related with the Pearson's correlation. Thereby, the multiple-correlation coefficient is the Pearson's correlation factor and also the determinant coefficient coincides with the square of Pearson's correlation factor. This is true because the study has been only made with two variables. This is, $R^2=r_p^2$ for each fit of linear regression according the models shown in Table 9. The determinant coefficient, R^2 is not zero and it must be close to 1 in order to accomplish the perfect linearity. Then, the first and third models fitted with linear regression can be considered linear because their determinant coefficients are 0.65 and 0.55, respectively. However, the second model shows a dependency between *x* and y_2 but it is not linear and for this reason the correlation factor is small, 0.34. Also the correct factor R^2 can be considered when the model has several independent variables in small sample.

On the other hand, the interpretation of the standard error tests the fit goodness. This value is better the closer to zero is. In our models the standard error are 0.041, 0.042 and 0.065, respectively. In addition, critical value F is greater than 0.05 (0.15, 0.30 and 0.099, respectively). In this analysis, the test of linear regression has been done with a 95% confidence level to accept the fit. This way, the linear dependence is evidenced again.

The scatter plot in Fig. 6 depicts the relationship between the influence of the type of OERs designed by teachers and the grades achieved by students. Firstly, a comparison between the grades for 2010/11 and 2011/12 courses has been done. This way, the influence of an OER as the video logs, which were introduced in 2011/12, can be shown. Fig. 6a includes the linear regression lines of the courses 2010/11 and 2011/12 separately, taking into consideration 83 and 69 assessments (Table 1), respectively. The only methodological difference in both courses was the video logs. Secondly, figure 6b includes the linear regression lines of both courses 2010/11 and 2011/12 jointly. Thereby, it can be established a comparison between the grades achieved by students when they use or not use new OERs designed by teachers, such as video logs, OCW-Blog, and applets to simulate Computer Networks. Given the dataset of assessments, these have been grouped into two sets: the first set from the course 2007/08 to 2009/10 (140+115+94) and the second set from the course 2010/11 to 2011/12 (83+69). In this case, the only methodological difference between the two groups is to use or not new OERs. For both experiments, a descriptive statistical analysis is shown in Table 10. The main conclusions are: (i) the video logs cannot be considered an improvement if we take into consideration the comparison of the courses 2010/11 and 2011/12 separately, being that the mean, median and mode slightly better for 2010/11 when video logs were not used. (ii) OCW-Blog, applets and video logs jointly can be considered an improvement, because the statistical values are slightly better in spite of the weak negative influence of the video logs. These results contrast with the students' opinions which show a strong positive appreciation about the video logs.

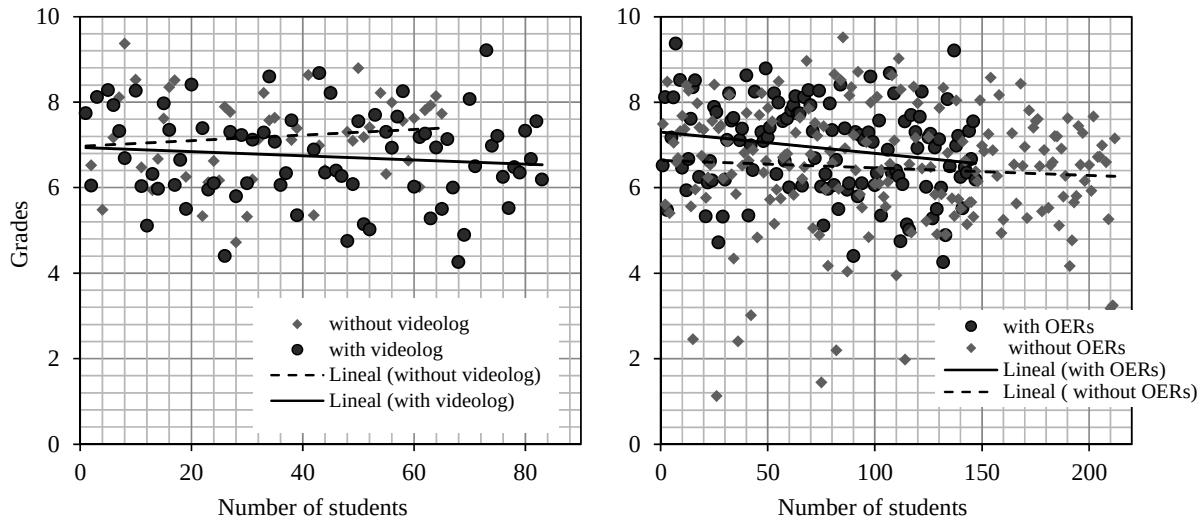

Fig. 5. Grade dataset dispersion and regression lines (data obtained from assessment tests). a) Courses with video logs are compared with courses without video logs. b) Courses with new OERs (video logs, OCW-Blog, Applets and Simulator) are compared to courses without novel OERs

	Dataset Descriptive Statistic							
Variable Concept	*Mean*	*Stand. Dev.*	*Median*	*Mode*	*Stand. Error*	*Kurtosis*	*Skew*	*Confidence Level*
2010/11 and 2011/12	6.91	1.08	7.09	8.21	0.097	-0.51	-0.19	0.19
2007/08, 2008/09 and 2009/10	6.43	1.54	6.56	5.85	0.090	4.47	-1.44	0.17
2011/12	6.73	1.08	6.69	6.06	0.126	-0.43	-0.09	0.25
2010/11	7.19	1.04	7.34	8.21	0.147	-0.46	-0.33	0.29

Table 10. Dataset descriptive statistic for the linear regressions shown in Fig. 5

5.3 Discussions

The results commented in previous sections show that learning process is enhanced using a set of OERs such as blogs, OCWs, videos and interactive simulations. A student opinion survey and three tests based on statistic correlations and three regression analysis, were conducted to examine if there are any assessment grade differences from the academic years 2007/08 (without OERs) until 2011/12 (with 5 type of OERs). In particular, the student interviews and statistical analysis reported in this paper show that:

- The educational resources such as OCWs, blogs, video logs and simulators (KIVANS, applets with EJS) have a good student acceptance. The best acceptance rate is obtained by video logs. Notwithstanding, the use of video logs by itself does not increase the learning performance and this resource should be combined with other ones like OCWs or blogs to get a significant improvement.
- The students have obtained higher grades when they have used these new educational resources. Mainly, over the last three courses, there are more students with a success rate greater than 7 out of 10 points.
- At the same time, the number of students who achieved an excellent level of knowledge has been increased while the number of students who drop out the studies has been reduced. The interpretation of statistical analysis evidences a linear dependency between OERs and excellent grades to pass the subject.

- However, a moderate increment of students who pass the assessment with a minimum positive grade is achieved. For this reason, we can note that there is a dependency between students who pass the subject with low grade and the used OERs. But this dependency is not linear.
- Furthermore, the regression analysis between the academic courses 2007/08, 2008/09 and 2009/10 (without OERs such as OCW-Blog, video logs and applets based on KivaNS) and the courses 2010/11 and 2011/12 (with OERs) have shown that the academic grades have improved.

Thus, summarizing, it can be deduced from this study that the effectiveness of learning is better when OERs are jointly used as was shown in Section 5. Hence, this work evidences of the usefulness of OERs in the learning process for subject Computer Networks.

6. Conclusion

This paper has described the educational impact generated in the students of a Computer Networks subject for using a set of OERs on a blended-learning methodology. These technological resources and tools, which are involved in a specific educational methodology, have been used to motivate the students, to encourage student participation and to enhance collaborative relationships.

With the aim of validate the above described advantages, authors have analysed the student perception and the learning outcomes. Specifically, authors have performed three tests based on statistic correlations and three regression analysis in order to prove the relationship between grade achieved by students and the number and type of OERs used in the learning process. From the results obtained, it can be deduced that the effectiveness of learning is better when OERs are jointly used. Thus, this work validates the usefulness of OERs in the learning process for Computer Networks subject. Even though the satisfactory results obtained and the stated objectives accomplished, the approach presented in this paper has limitations. The intensive use of OERs without the teacher's support cannot guarantee students to pass the subject because there is not a proportional relation between the achieved grades and the number of hours used by the students in the OERs. This issue may be due to the analytical study performed does not take into account the student profile and his behaviour in the use of OERs. Student surveys were anonymous, although their assessments are known.

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