Web-Based OERs in Computer Networks*

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Learning and teaching processes are continually changing. Therefore, the design of learning technologies has gained the interest of educators and educational institutions from secondary school level to higher education. This paper describes the successful 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 that are based on a blended-learning methodology, have been employed to teach the subject of Computer Networks. We have not only verified that the application of Open Educational Resources (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 first by a study of both students' opinion and students' behaviour over five academic years, and, secondly, by 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 has usually been applied to adapt the contents and methodologies of the topic to the ESHE [2, 3], which determines that traditional education must be combined with a good distance education in order to provide students with flexibility. In this new educational context, Open Educational Resources (OERs) [4] play an important role, because they are designed for distance self-learning. The work presented in this paper shows the successful application of using a blended-learning methodology in the subject of Computer Networks course in the Computer Science Engineering degree at the University of Alicante, in Spain. These OERs are used to provide students with a way of configuring their own free schedule according to their requirements and their level of knowledge.

As many authors consider [5–7], teaching Computer Networks successfully 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 correct 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 to obtain a deeper understanding of computer networks. Most students adopted only a hands-on learning strategy, providing them with practical exercises using hardware devices in a Local Area Network (LAN) [6] in order to build high-performance networking systems [8]. Other approaches have just used 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 by 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 OpenCourse-Ware (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, describing 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 completed by students to find their opinion of the methodology and to assess the approach's efficiency. In addition, a statistical study to find the relationships between 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 one

Table 1. General data for courses according to academic years

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
No. of practical hours (P)	45	45	45	45	45
No. hours of theory (T)	30	30	30	30	30
No. of students	140	115	94	83	69
No. of lectures (T)	1	2	2	2	1
No. of lectures (P)	1	3	3	2	3
No. of students that pass	54	58	24	34	25

regular lecture (2 hours per week) and one regular practical lesson in a lab (3 hours per week). Details of the courses can be seen in Table 1. The average age of students was 21–22 years. 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 few 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 that has been implemented allows one to 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.

The lectures are based on a set of slides that allow 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 the consolidation of 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 that consist of short multiple choice questions, short answer questions and/or short exercises. The new evaluation methodology requires the system must be provided with a tool that allows students to mitigate the problems in understanding the concepts and a 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 these problems. These self-assessment tests are very similar to the evaluation tests, but the marks obtained by the students are considered only by

themselves to verify that they understand and know the most important contents. In this way, students can detect learning problems while reducing their fear of the assessment review.

The theoretical concepts are evaluated continuously by means of questionnaires, exercises and problems delivered throughout 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 carried out on their use by students. In addition to educational platforms such as Moodle [11], other types of resources have been designed and implemented as supplements: Open-CourseWare (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 OpenCourse-Ware project [18]. MIT defined an OCW as course materials that are used in the teaching of almost all undergraduate and graduate subjects that are available on the Web, free of charge, to any user anywhere in the world. It is important to note 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, courseware should be developed as part integrated into courses that consist of a mix of multimedia materials (such as textbooks, videos, software, links and interactive simulations). This fact is becoming increasingly important because the students have become more demanding and exacting. They are not satisfied just with the electronic resources of the lectures with additional support. Students request more interactive content in an OCW because the slides and files

on the subject content are hard to understand without the context of the course. Our OCW [19] has been created as an interactive Web repository that stores OERs. These OERs are composed of multimedia videos, electronic documents, interactive simulations and several external links in order to provide more information to the students.

The proposed OCW [20] has been organised as follows: presentation, aims and scope, contents, educational methodology, evaluation, educational resources, bibliography and Internet resources. The educational contents and the implemented resources, as well as the tools to provide feedback to the students, have allowed us to achieve the 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, which have been created by the teachers, on the practical and theoretical contents as well as the 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 instantly

appears. 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 interactive simulations applets [16, 23]. This type of resource will be commented on in the next section.

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

Reference [12] shows how MIT has integrated an evaluation programme that probes three aspects: what student profile has a user who accesses OCW, how do 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 have been accessible since December 2010. Up to now (February 2013), more than 3701 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
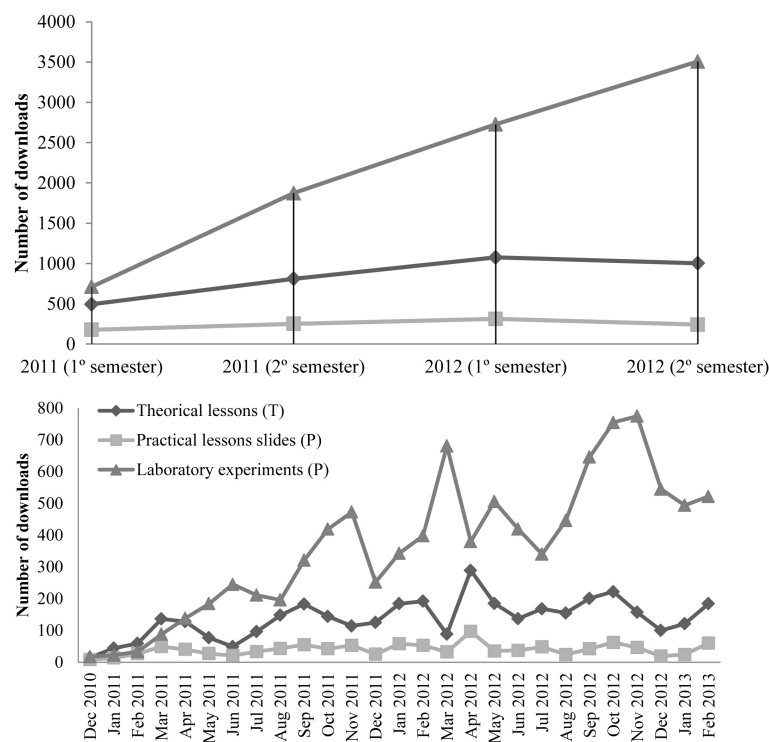

Fig. 1. Evolution of number of downloads by semesters and months from presented OCW.

Table 2. Access and download rates for the OCW resources

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

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 similar percentages. The received visits and downloads have been 1.4% and 1.1% from the 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 unavailable. Table 2 shows the download information classified by years and type of materials.

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

3.2 Blog

The blogs, in an educational context, have been gaining popularity over recent 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. Blogs were mainly 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 focuses 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: content and objectives, programme, bibliography, links to educational resources (free-open software, simulations, videos, etc.), links and information about other courses on Computer Networks, and relevant news related to the subject. Related news such as new communication technologies and systems are commented on, and courses about computer networks offered in Spanish universities and private companies have been added in order 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.

Several reasons have led the authors to use their own educational blog. They are mentioned in [19]: perceived enjoyment, codification effort, compatibility, perceived ease of use, personal innovativeness, enjoyment in helping others, school support and perceived usefulness. 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 related to the theoretical classes. In addition, e-learning tools, like this one, can increase the participation and collaborative relationships between students, since they can share experiences or opinions during the lectures.

This blog has been accessible since June 2010. Until today (February 2013), 83 and 262 students from the University of Alicante who are enrolled on the Computer Networks course have had access to the blog in these two last academic years, respectively. Furthermore, from February 2011, the visit statistics have been obtained by means of the Google Analytics tool (Tables 3 and 4). This tool allows one to know the location and language of

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

Visit duration	Visits	Page views	Count	Frequency	Recentness
< 1 min.	86.1%	63.3%	1	86.3%	81.4%
1–3 min.	5.2%	10.5%	2	7.3%	8.3%
2–10 min.	5.1%	13.3%	3	2%	3.2%
> 10 min.	3.6%	13%	≥3	4.4%	7.1%

Table 4. Most popular contents of the blog 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 on 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

visitors from outside of the University of Alicante. The visitors have been found to come mainly from Spain (21%), Latin America (56.6%), and North America (0.8%), countries where there are Spanish speaking communities. The rest, 21.5%, access from other geographical areas. The 13.7% (2032 visits) are returning visitors vs. 86.3% (12 829 visits), which are new. Before February 2011, statistics have only been available to visitors from inside the University of Alicante (see the Section 5). In addition, three aspects of the behaviour of visitors have been measured. They are: the frequency and the recentness (Table 3), which pages are the most frequently accessed and how much time is spent on the page 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 accessed other pages of the blog. Sometimes, the bounce rate is high because the visitors have found what they were looking for. Therefore, they do not need to keep browsing the blog. On the other hand, the average time spent on the page is the ratio between the total time of the visits and the number of visits.

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

3.3 Video logs

The development of multimedia technologies, the Internet and automatic capture to create presentations [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 unavailable to 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 understanding about concepts on the working of protocols. 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 a 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 as it would be if carried out in a 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 and select those that are properly explained and better described. Then a collection of the 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 programming is required to prepare the simulation and obtain the results. The 'cnet network simulator' is another interesting free option [35] that simulates different network layers and technologies. However, 'cnet' mainly focuses on evaluating the performance of data transmissions and it can only be executed on Linux or Unix systems. Another

program, 'TCP Flow Control Simulation and Visualization' [36], is a good example of a 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 give reasons to build software applications to simulate the behaviour of LANs. In addition, virtual laboratories allow the students learn in their own way. Moreover, good learning with virtual laboratories and simulators must be accompanied by guided experiments in the form of courses as is commented on 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 line of research, other recent work is the presented in [40].

4.1 KivaNS

KivaNS [32] is a free and open source software application designed in Java to simulate and study how IP (Internet Protocol) works. In order to do this, KivaNS also includes the simulation of aux-iliary 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 and 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. Figure 2(a) 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.

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 for teaching specific simulations about aspects about working of networks quickly. For this reason, the authors have combined the use of the software EJS [41], with the simulation engine of KivaNS. EJS is an open-source
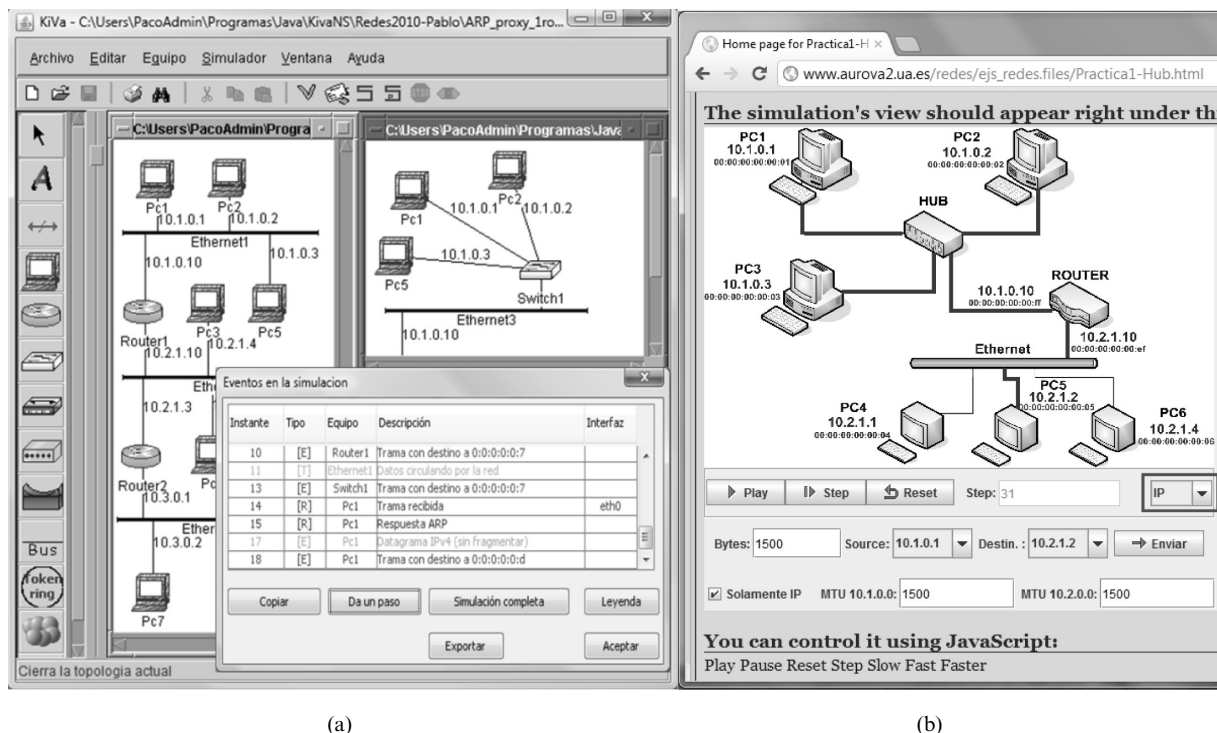

(a)   (b)

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

tool developed for the creation of interactive simulations, in the form of Java-applets (see Fig. 2(b)), which can easily be embedded in a Web page or even in an LCMS such as Moodle. The interface of EJS allows users to develop simulations quickly and easily. 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.

- The operation of ARP
- The functioning of bus or switched in Ethernet networks
- The differences in the functionality among network devices
- The working of IP, even considering fragmentation of data
- IP addressing and broadcasting
- The 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 the 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 processes of students in engineering. Many teachers are already using these tools in their teaching but an isolated way, without combining them with other tools.

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

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. 3(a). This comparison was done from the viewpoint of handling (easy to use), organisation (how the contents were structured and if they were easy to find), update frequency and the relevance of their 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 can be seen in this figure, 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 that 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 the blog. In addition, the average value is always equal or larger than 3 for all aspects. In particular, it is 4 in regard to the relevance of resources developed by the authors and commented on in Sections 3 and 4.

On the other hand, the students were asked whether the learning process is improved by using blogs and OCW and wha is the degree of improvement. According to the opinion about blogs, 78.3% (equal or larger 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 above). However, the students considered (they voted 4 in the great majority and 78.2% vote 3 or above) 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 became more fluid (71.7% of students). They thought that the comments about information on the blog could greatly enhance and help the communications between students of different universities or the same university.

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

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

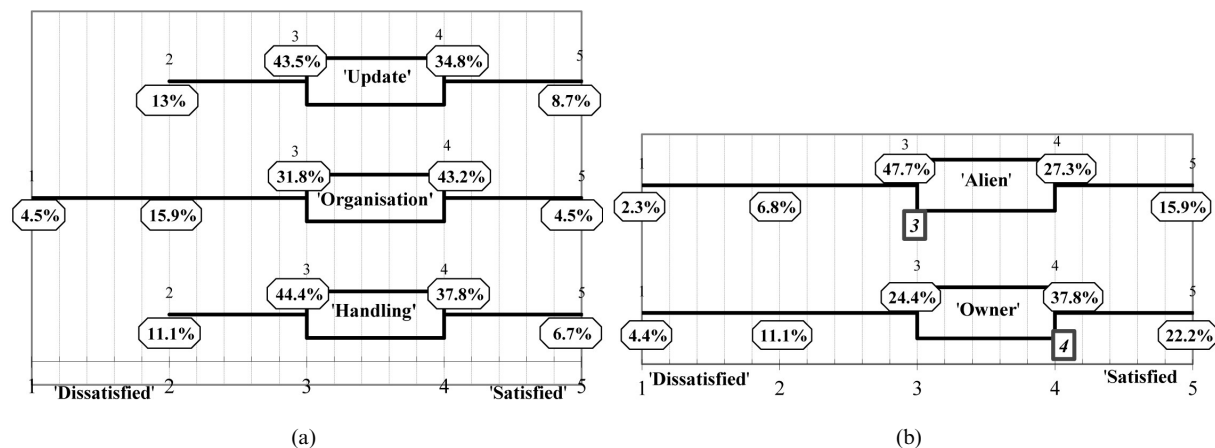| No. accesses/week	Blog	OCW	No. hours	Other resources (Internet)
Never	6.8%	33.3%	Never	8.5%
1	52.3%	46.7%	0–1	29.8%
2	36.4%	11.1%	1–5	46.8%
2–4	4.5%	8.9%	5–10	8.5%
>4	0%	0%	>10	6.4%

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 provided by the blog.

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 the OCW in combination with masterly lessons useful. 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 the 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 more 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 that were accessed very often are the news and the details of the programme of practical and theoretical classes. The sections with fewer hits were the teacher information and the objectives of the subject.

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 now had 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 more).

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 the subject of Computer Networks in face to face educational methodology. Interpreting the results shown in Fig. 5, 81.5%, 82.3% and 71.7% voted 3 or more on 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, the authors provide triangu-
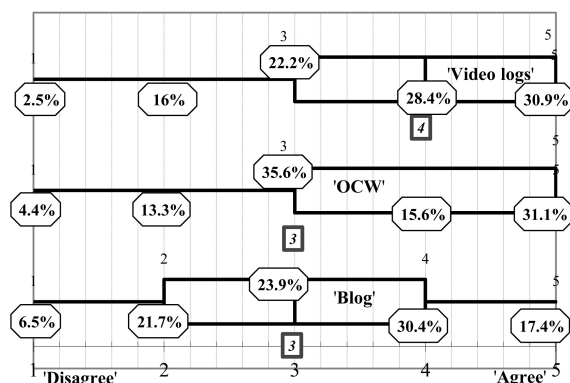

Fig. 4. Comparison of educational tools: Goodness level of these tools to enhance learning in face to face methodology (data obtained from a classroom survey).

lated 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 no 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 students' grades that have been 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 comprises 501 students. These are the students who have taken the Computer Networks course from 2007 until today. In addition, it is known that 140 students have never used OERs and the remainder, 361 students, have used one or more OER (Table 1). Furthermore, the analysis has been made by normalising the data for all samples. Thereby, the number of data is the same for each sample so they can now be compared. 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).

Over the last five 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 five new OERs have been used by students in the last year, such as simulators, blogs, OCW, videos, etc. The study examines the relationship between the number of educational digital resources and the achieved grades (Table 8).

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 used in previous academic years. These can be viewed in Table 7. Three unilateral and bilateral tests have been performed to find the correlation between the two variables, x and y_i where $i = 1 \ldots 3$.

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 Student t-distribution for these two independent samples, x and y_1, shows 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 in order that the difference between the means of the two variables is significant (5% level). In this case, both means have no significant variation.

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 student's t-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 $\geq$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 student's t-distribu-

Table 6. Grade acquired by our students from 2008 until 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 7. Educational resources used in each academic year

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
No. of resources (x)	0	1	2	4	5

tion 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 the 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. The Spearman correlation is less sensitive than the 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 the 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.

On the one hand, the fit of the linear regression is closely related to the Pearson's correlation. So, the multiple-correlation coefficient is the Pearson's correlation factor; also the determinant coefficient coincides with the square of Pearson's correlation factor. This is true because the study has been made with only two variables. That is, $R^2 = r_{p^2}$ for each fit of the 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 the 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 a small sample.

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

The scatter plot in Fig. 5 depicts the relationship between the influence of the type of OER designed by teachers and the grades achieved by the students. First, a comparison between the grades for 2010/11 and 2011/12 courses has been done. In this way, the influence of an OER as the video logs, which were introduced in 2011/12, can be shown. Figure 5(a) includes the linear regression lines of the courses

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

Variable Concept		Pearson's and Spearman' Correlation				
	Variable label	Corr. factor r_p	Corr. factor r_s	t-student	p-value two tail	t-critical value
No. of students who achieved a high grade ($\geq$80%)	y_1	0.74182	0.8	2.47415	0.06866	2.77644
No. of students who passed the exams ($\geq$50%)	y_2	0.58463	0.6	1.61171	0.18231	2.77644
No. of students who dropped out the course	y_3	–0.80765	–0.9	2.36009	0.07765	2.77644

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

| Variable concept | β_{0i} | β_{1i} | Mult. corr. coef | Least squares regression analysis | | | F | Critical value F |
				Det. coef R^2	Correct R^2	Stand. error		
$y_1=\beta_{01}+\beta_{11}x$	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

2010/11 and 2011/12 separately, taking into consideration 83 and 69 assessments (Table 1), respectively. The only methodological difference between the courses was the video logs. Secondly, Fig. 5(b) includes the linear regression lines of both courses 2010/11 and 2011/12 jointly. Thereby, a comparison can be established between the grades achieved by students when they use or not use new OERs designed by their teachers, such as video logs, OCW-Blog, and applets to simulate Computer Networks. The dataset of assessments 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 the use or non-use of new OERs. For both experiments, a descriptive statistical analysis is shown in Table 10. The main conclusions are: (1) the video logs cannot be considered to be an improvement if we take into consideration the comparison of the courses 2010/11 and 2011/12 separately, as the mean, median and mode are slightly better for 2010/11 when video logs were not used; (2) OCW-Blog, applets and video logs jointly can be considered to be an improvement, because the statistical values are slightly
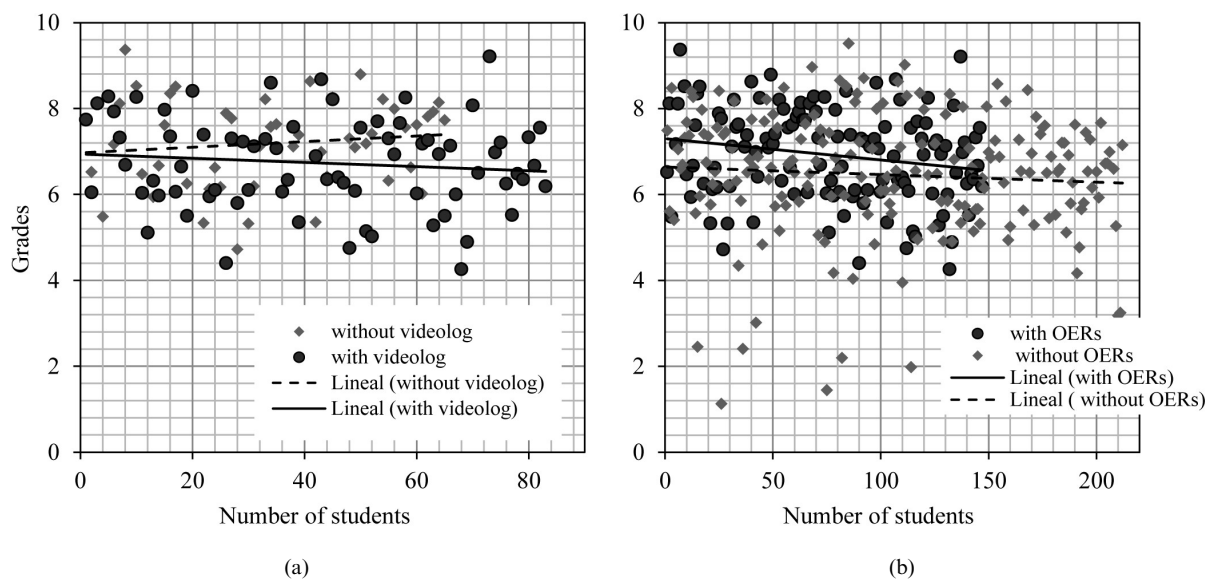

(a)

(b)

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 with courses without new OERs.

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

| Variable concept | Mean | Dataset descriptive statistic | | | | | | Confidence level |
		Stand. dev.	Median	Mode	Stand. error	Kurtosis	Skew	
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

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 of the video logs.

5.4 Discussions

The results commented on in previous sections show that the 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 five types of OERs). In particular, the student interviews and statistical analysis reported in this paper show the following.

- The educational resources such as OCWs, blogs, video logs and simulators (KivaNS, applets with EJS) have good student acceptance. The best acceptance rate is obtained by video logs. Notwithstanding, the use of video logs by themselves does not increase the learning performance and this resource should be combined with other resources, such as OCWs or blogs, to get a significant improvement.
- The students obtained higher grades when they used these new educational resources. 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 from 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 a low grade and the OERs used. 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 improved.

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

6. Conclusions

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 validating the above advantages, the authors have analysed the student perception and the learning outcomes. Specifically, the authors have performed three tests based on statistic correlations and three regression analysis in order to prove the relationship between the grades 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 the Computer Networks subject. Even though the satisfactory results obtained and the stated objectives are accomplished, the approach presented in this paper has limitations. The intensive use of OERs without a teacher's support cannot guarantee that the students pass the subject because there is no proportional relationship between the grades achieved and the number of hours spent by the students in the OERs. This may be because the analytical study performed does not take into account the students' profiles and their behaviour in the use of OERs. Student surveys were anonymous, although their assessments are known.

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