A Computer Networks Experience in the Transition to the European Space for Higher Education

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ABSTRACT
Since the Bologna declaration on the European space for higher education (ESHE) was signed in 1999, around 50 countries (including the 27 member states of the European Union) have joined this effort to homogenize higher education (initially in Europe, although many other countries have already embraced the initiative). The ESHE was stated to be finished by 2010 (all the university programs should be adapted by then). In Spain, notorious changes have been required in the different programs and courses, both in the educational framework (structure, study length, etc.) as well as in the educational methodology that now follows a more 'student driven' approach. This paper is describing the education experience in a Computer Networks course that is taught in the first Spanish Computer Science program that has been officially adapted to the ESHE in the Universidad Carlos III de Madrid.

Categories and Subject Descriptors
C.2.0 [**General**]: *data communications.* C2.2 [**Network Protocols]**: *protocol architecture, routing protocols*. C.2.5 [**Local and Wide-Area Networks**]: *Ethernet, Internet.* C.2.6 [**Internetworking**]: *routers, standards.*

General Terms
Design, Theory.

Keywords
Keywords are your own designated keywords.

1. INTRODUCTION
The Bologna declaration on the European space for higher education (ESHE) [1] signed in 1999 started a convergence process with the main objective of creating a common space of higher education "to enhance the employability and mobility of citizens". The deadline of this process was year 2010 and by then all the structural and methodological changes had to be assumed by the countries.

In particular, (1) the adoption of a system based on two cycles (undergraduates and graduates) that (2) should be easily comparable (by means of the Diploma Supplement that normalizes the way to describe the studied program) and that is based on (3) a system of credits that commonly fixes the amount of work developed by the student along the different courses (ECTS, European Credit Transfer System; one academic year is 60 ECTS credits).

In Spain, the two cycle structure has been implemented as graduate (bachelor) programs of 4 years (240 ECTS credits) and master programs of 1 or 2 years (60-120 ECTS credits). The implementation also implies important methodological changes with a reduction of the total number of lectures and an increment of students' homework. The first graduates coming from these new programs in Spain are from the Universidad Carlos III de Madrid [2].

This paper describes the educational experiences carried out in the Computer Networks course that belongs to the third year (out of four) of the Computer Science degree program and compares it with the course taught in the pre-Bologna degree.

Section 2 describes the framework of the course within the Computer Science program of the Universidad Carlos III of Madrid. Section 3 comments the deployment requirements that the university has established for every program. Section 4 describes the course contents and section 5 the course organization, including methodology.

2. PROGRAM FRAMEWORK
The Universidad Carlos III de Madrid has established a common framework for all the degree programs. Each one of the four academic years (60 ETCS) is organized in two semesters and almost all the courses are 6 ECTS (so there are 5 courses per semester).

There are 15 weeks per semester (September-December and February-May) and every week there are two 90 minutes sessions per course. One of these sessions is typically devoted to theoretical lectures with up to 120 students per class. In the other session a more practical approach is followed (with activities like tests, labs, use cases, discussions, etc.) and the students are separated in groups of up to 40 persons, so as to better accommodate the different activities.

All these activities are also encouraged from the University since a continuous evaluation methodological approach is now being required. This methodology is enforced by the

idea behind the new credit system (ECTS). In the pre-Bologna programs, 1 credit was equivalent to 10 lecture hours. A new credit (ECTS) is defined as around 25 hours of student work. A 6 credits course means 150 hours and divided by 15 weeks it means that students must work around 10 hours per week per course (including the 3 hours dedicated to lectures). This extra homework may just be the classical exercises but also practices, auto-tests, readings and in general different activities that are designed to support and complete the knowledge acquired in the theoretical lectures. All these activities are normally the core part of the continuous evaluation schema of the courses.

On the other hand, in the pre-Bologna programs, there were particular final examination periods where students had to take all their exams. There were two chances (exams) to pass a course per year. With the new schema, it is mandatory to evaluate at least 40% of the course based on continuous evaluation, so only 60% maximum is evaluated on the final examination period (and there are many courses that are 100% continuous evaluation, so there is no final exam for them).

3. COURSE FRAMEWORK

The Computer Networks course [3] that belongs to the Computer Science program is an introductory networking course that is supposed to be completed by an advanced master course. This is the only computer networks course of the degree program and it provides a brief overview in order to enable students to understand network concepts going from the link layer to the application layer. The course covers the generic concepts associated with protocols of the different layers and particularizes the concepts to specific real protocols: Ethernet, IP, TCP/UDP, DNS.

The fact of being the only networking course in the program turns it into a special networking course. The pre-Bologna program included three different networking courses: a link layer centered one, a network and transport layer course and an application layer course. However, when the Computer Science program was adapted to the ESHE and knowledge was structured in degree and master programs, this course remained alone in the degree. This meant that we had to adapt the course so as to make it self-content and at the same time provide a reasonable amount of networking concepts for a graduate level without assuming that students were going to take the master.

With these restrictions, and understanding that it is a Computer Science program (and in the University there is a specific Computer Networks program) this course has been design to be mainly focused on the network and the transport layer and to provide an overview of the link layer and the application layer (the application layer will be further detailed for those students that decide to go for the master program).

We have been teaching this kind of network/transport centered courses on the pre-Bologna Computer Science program and a similar one on the Computer Networks program. Half of these courses were based on theoretical sessions and the other half were lab practices (each theoretical session lasted 100 minutes and every practical session 2 hours). The final score was obtained by means of a final exam, 60%, and the mark obtained in the lab practices, 40% (pretty much the same as many other courses in the program).

This type of ‘classic’ schema is not supported anymore by the new framework defined by the University that is in fact supporting courses with less theoretical sessions and a more intensive activity focused in student learning (the so called ‘student driven’ approach).

The challenge we faced here was that we had to move from a fully lecture based course, where all the concepts were detailed in the lectures and evaluated at the end of the semester, to a new schema where students’ work at home is crucial and where there is not enough time to explain all the concepts in the class.

These are the different objectives that we considered when designing the course:

- Integrate and adapt the contents of the three pre-Bologna courses, from the link to the application layer so as to cover a reasonable overview of the networking principles.
- Design the theoretical sessions to include only the most relevant concepts.
- Design the homework and the practical sessions so as to be synchronized with the theoretical sessions and to cover the rest of the contents not explicitly treated in the lectures.
- Design a proper evaluation methodology so that students are motivated to do a continuous work in class (and even more challenging, at home).

4. COURSE CONTENTS

As it has been mentioned, this is the only network course of the program, so an overview is provided from the application to the link layer with a special stress on the network and transport layer. In particular, these are the contents (see also [3]):

- Application layer: generic concepts of application layers, services offered by the transport layer to the application layer, DNS as an example of application, socket programming.
- Transport layer: multiplexing, UDP, TCP, introduction to TCP congestion control.

- Network layer: datagram networks, routers, NAT, ICMP, routing algorithms, Internet routing.
- Link layer: multiple access protocols, ARP, Ethernet

Unlike the situation we had in the pre-Bologna course where the study program imposed a bottom-up approach (with a previous and required course about the link layer and a subsequent course about the application layer) here we have the freedom to choose how to do it.

Based on our experience with the students of the Computer Science program and comparing them with the ones of the Computer Networks program, we found that they typically have a more practical profile and they are for instance, more used to application programming. This is the reason for us to change from the previous bottom-up approach to a top-down one, where students can clearly see the application of what they are going to learn later on, from the very beginning, and they can even start programming network-based applications almost from the first week.

In our previous courses we were not using a particular reference book or articles. However due to the considerable amount of work that students have to do on their own and due to the synchronization requirements that we must have between the different activities, we decided to use a single reference and we chose the Kurose/Ross text [4] that is following the top-down approach that we wanted to use here.

5. COURSE METHODOLOGY

For every University course, all the different activities, homework, lab sessions, lectures and evaluations have to be carefully detailed in a work program for the 15 weeks (14 regular weeks plus 1 additional week in case it is needed to make adjustments, so there are in fact 14 theoretical lectures and 14 practical sessions), specifying the type of activity, estimated duration, date, place, etc. The work program is made public to the students even before the course starts and it is considered a kind of contract between the students and the teachers that should not be altered.

This is particularly important in this Compute Networks course since one theoretical lecture is not normally continued in the following one and is not the continuation of the previous one (as it actually happened in the pre-Bologna courses). It is in the work program where the appropriate order of knowledge acquisition can be followed since all the activities are properly allocated.

In addition, a guide is given to the students so that they can clearly identify in the Kurose/Ross text the contents that will be covered in the theoretical lectures, the contents that they must work at home and the contents that will be part of the practical sessions. This way, students can prepare the theoretical lectures in advance, although it is not mandatory, in order to be able to understand the explanation.

To complement the theoretical lectures, the practical sessions, that are in general including evaluations, have been design so as to encourage students to prepare the theoretical sessions and to motivate them to understand the different contents of the course.

As it has been mentioned, there are 14 practical sessions. In 6 of them the students will have a short test at the beginning during 10 minutes where they will demonstrate their understanding of the previous theoretical session and of the part of the Kurose/Ross text set as homework for that date. The possible short questions (review questions) that may be asked, are selected from the set of short questions available on the reference book. In order to motivate students to prepare the questions (since there are normally a lot of them in the book), a subset is selected (10-15) and published a week before. Students know that we will be asking them 2 or 3 questions from the subset.

4 out of these 6 sessions are completed with use cases discussions. The students are grouped in couples and they must solve two use cases from the set available in the book for the chapter under consideration (again a subset of all the available use cases is provided the week before so students have time to prepare them and are also motivated to do it). At the end of the session, some of the student groups are randomly selected in order to have an oral discussion of the exercise with the rest of the class and some others are selected to be corrected by the teachers). A maximum of two use cases are corrected per student.

The other 2 remaining sessions with short tests at the beginning are completed with 2 short practices (in one of them the students must program a ping application and in the other one they must understand DNS by means of traffic monitoring).

3 out of these 14 sessions are devoted to knowledge tests (long tests that will last the whole class). The teacher will select several use cases from the reference book and the student will have to solve them individually (there is no previous selection of a subset here, and any use case on the reference book can be asked).

And the rest of practical sessions are including short theoretical-practical explanations needed to solve the proposed exercises and practices.

On top of these 14 sessions, there are 4 additional sessions fully dedicated to hands-on labs: 2 sessions to configure routers and 2 sessions to practice with the whole protocol architecture explained in the course by means of traffic monitoring.

The evaluation in this course has been summarized in figure 1. This course is completely evaluated following the continuous evaluation approach. One of the most important problems that have been seen in other courses is that students tend to leave the course in case they fail several tests at the beginning (or in case they just miss the exam for

whatever reason). In order to encourage student participation and try to avoid they leave the course, the students are evaluated over 120 points (while they only need 50 points to pass the course). The 6 short tests, the 2 short practices and the 2 exercises they must do, are scored 5 points each (so there are 50 points assigned to these short activities specifically design in order to enforce student participation and to prepare the theoretical lectures). In addition, the 3 long lab practices are scored 10 points each and the 3 long tests are scored 20 points each (a maximum of 40 points is set for the sum of the 3 long tests).

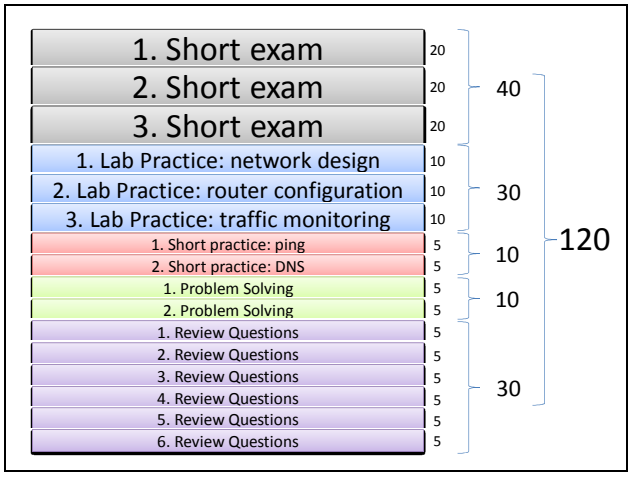

Figure 1. Evaluation chart

6. CONCLUSIONS

Although it is still very soon to have conclusions (the course was offered for the first time by fall 2010 and 190 students were registered in the course), the first results are considerably promising.

The number of students that passed the course is high (90%). Being this a nice indicator it does not mark a difference with the pre-Bologna course since the results there were also quite good.

Initially it may be thought that this success could be because of scoring the course over 120 instead of 100. We have verified that this is not the case. The effect of this over scoring has been an extraordinary amount of outstanding students and for the following edition of the course we will have to review the amount of over scoring (although by no means we will eliminate it, since it has perfectly fulfilled its purpose). But it is also true, that there is no student actually passing the course that would have failed in case no over scoring had been used.

The best indicator for us is the student participation. Only 2% of the students left the course after the first tests. The rest of them were regularly attending to the different lectures and completing the different activities and evaluations (not all the students completed absolutely every activity but it is reasonable, assuming the 20% over scoring they have). We really consider this a good result since it has been confirmed that this is not common in the rest of the courses.

The evaluation that the students made of the course itself has also been quite good considering that this is the first edition (scoring over 4 points out of 5 in media in the global satisfaction indicator).

7. REFERENCES

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