A B-LEARNING APPROACH FOR ELECTRICAL ENGINEERING BASED ON WIRELESS ACCESS TO PEDAGOGICAL E-CONTENT

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Abstract: This paper describes a novel pedagogical approach and its application to undergraduate Electrical Engineering courses. A b-learning model is proposed where students are subject to different types of interactions and diverse learning experiences characterised by the type learning session and pedagogical agent in use. These include face-to-face teaching sessions in the classroom, standalone e-learning sessions, working groups and supervised laboratory work. A wireless LAN infrastructure, as part of the Portuguese Electronic University Project, is used for the e-learning component of the proposed approach. In practice, this is an application of the "*anywhere, at anytime*" concept to learning processes by extending classroom boundaries in both space and availability domains. From a technical point a view, the paper addresses the information network infrastructure used and its quality of service in multimedia communications, the e-content generation, its characteristics, requirements and possible adaptation to heterogeneous environments. A student survey was conducted to evaluate technical and pedagogical aspects of the learning process using the proposed model. The results show this is a promising approach towards flexible learning in Higher Education Institutions and also revealed that students tend to adapt rather slowly to emerging pedagogical approaches, though they are truly in favour to use IT in their own learning processes.

1 INTRODUCTION

Nowadays, there is a fast growing use of information technology (IT) in education where Higher Education Institutions are, to a certain extent, responsible for opening new frontiers by accepting new challenges and foreseeing the future. In the last decade, Higher Education in general has experienced profound changes mainly driven by IT, which includes not only the pedagogical processes, but also management and administrative processes that became totally dependent on computers, software applications, databases, and communication networks of all kind (Duderstadt, 2001). The integration of IT in today's undergraduate education has appreciably modified the nature of student interactions within their own learning processes. By simple comparison, it is obvious to realise that the heart of IT is comprised of similar components as the pedagogical process roots: information and communication. As a consequence of the continuous evolution of information and communication technologies, innovative learning-oriented applications and pedagogic approaches have been proposed (Castro et al., 2001).

Wireless communication technology is undoubtedly a field where fast technology advances have been witnessed almost on a daily basis over the last few years. However, only recently, wireless technology has become cost effective and therefore attractive to be used in education (Nyiri, 2002) (Tzu-Chien et al., 2002) (Lehner et al., 2004).

In this paper, a blended learning (b-learning) model supported by wireless technology, is proposed. This work is also a response to the new challenges and opportunities created by the Portuguese Electronic University Project (e-U), which is a pioneering practical attempt to reshape the Higher Education institutions in Portugal. The wireless local area network (WLAN), as the core of the virtual campus is a major component of the supporting technology along with content generation and storage equipment. Recently proposed

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approaches for content generation were taken into account (Schutz et al., 2003) (Chen et al., 2003) and a novel content adaptation method to deal with heterogeneous mobile environments, is proposed.

The b-learning approach implemented in the course of this work is built on top of an efficient combination of technology, human resources and other intangible assets such as knowledge and interaction capabilities. It is demonstrated that such a learning model is possible to be deployed and it is useful from both the learner and academic institution perspectives.

The paper is organised as follows. Section 2 provides a general description of the information network infrastructure that supports the proposed pedagogic model. Section 3 describes the most important aspects of the multimedia content, specifically produced in the course of this work and used in e-learning sessions. Both technical and pedagogical aspects are addressed. In section 4, the proposed b-learning model for undergraduate engineering courses is presented, while section 5 deals with the evaluation of the whole process through a student survey that was carried out for the purpose of this work. Finally, conclusions are drawn in section 6.

2 INFORMATION NETWORK INFRASTRUCTURE

2.1 General Overview

The information network is mainly used in the e-learning sessions of the pedagogical process described in section 4 and consists of four distinct modules, i.e. Content Generation (CG), Content Manager (CM), Fixed Content Access (FCA) and Wireless Content Access (WCA), as shown in Figure 1. The CG module is responsible for the multimedia data acquisition and encoding processes and is comprised of external acquisition devices (e.g. video camera, microphone, VCR) connected to a personal computer by means of an MPEG-2 real time encoder board. The CM comprises of a specific media management application and a multimedia server. The encoded multimedia content is stored on a multimedia server via a local area network (LAN).

The system is based on a client/server software solution controlled by the CM through specific instructions to other modules, which allows one to deliver multimedia streaming of academic content, either real-time encoded from live lectures or produced off-line to (i.e. stored in the server) to fixed and mobile terminals using a fixed or wireless network, respectively. It supports several streaming formats such as AVI, MPEG, QuickTime, etc.

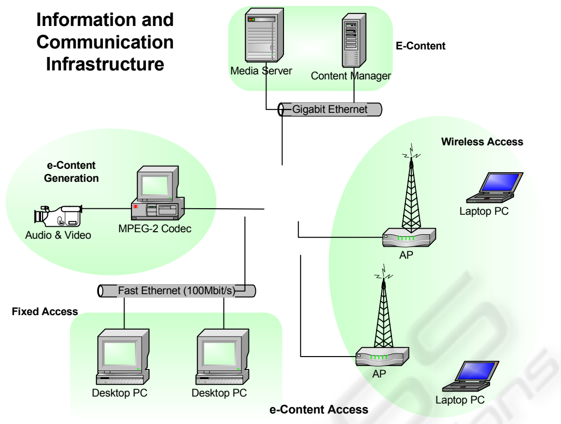

Figure 1: Block diagram of the general communication system.

The CM allows for scheduled services, appropriate content management and load balancing between different on-campus servers. The recorded audio and visual streams may be delivered to end users either in a scheduled mode, using IP *Multicasting,* or on request, using *Video on Demand* (VoD). The CM user interface was developed in Java to allow remote access from any web browser and enhanced security capabilities such as password protection for access to dedicated applications and encryption of multimedia content. Subsequently, the FCA module allows fast Ethernet access (up to 100 Mbps) to multimedia content from ordinary desktop PCs distributed among laboratories, classrooms and offices. Due to the limited number of fixed desktop PCs and their unavailability during daytime (e.g. while classes are in progress), the system was extended to provide additional access using fast wireless local area networks (WLAN). The WCA module is responsible to provide extended mobile coverage to users using handheld or laptop equipment. The wireless access requires the use of specific hardware compatible with the 802.11 standard (Institute of Electrical and Electronic Engineering ,1999), allowing transmission data rates as high as 54Mbps, as described in the next subsection.

The application used for viewing the encoded multimedia content runs on any machine or mobile terminal running on Windows operating system. The CM provides this user application with detailed information about all available e-content in the multimedia server, listing them in a hierarchical order to be viewed. The user may also select e-content *on demand* or even subscribe to other e-contents to be viewed at a later time. The application may be installed as a plug-in for any web browser or, alternatively, it can run as an independent application.

2.2 Wireless Content Access: Main Features

A. IEEE 802.11 standard

The international standard on wireless local area networks (WLAN) – IEEE802.11 (Institute of Electrical and Electronic Engineering ,1999) refers to the components of WLANs, which consist of a wireless network interface card (often known as station - STA), e.g. PCMCIA cards, and a wireless bridge referred to as access point (AP). The AP interfaces the wireless network with the wired network (e.g. Ethernet LAN), as shown in Figure 1.

The standard specifies Medium Access Control (MAC) and Physical Layer (PHY) for wireless connectivity for fixed, portable and moving stations within a local area. It operates using radio technology at the ISM (Industrial, Scientific and Medical) unlicensed frequency band of 2.4 GHz, capable of providing radio coverage up to 100 meters in an open environment. The standard considers a WLAN with 1, 2, 5.5, 11 and 54 Mbps data payload communication capabilities, depending on the radio modulation technique used to access the medium, i.e. Direct Sequence (DSSS) or Frequency Hopping Spread Spectrum (FHSS) (Institute of Electrical and Electronic Engineering ,1999).

B. Propagation and Coverage

Mobile WLAN systems rely on their design and appropriate radio planning for an uniform coverage in an arbitrary environment, such as the University Campus. The WLAN radio range is mainly dependent on the channel physical and temporal characteristics. In multimedia streaming applications, the perceived quality of the decoded content is greatly dependent on the quality of the received radio signal. In the case of e-learning applications, such as the one included in the b-learning model proposed in this paper, sufficient signal coverage in every access location is extremely important to ensure acceptable quality of service (QoS) delivered to learners. To this extent, a measurement campaign was performed in order to check the appropriateness of each potential access location identified for the current survey.

2.3 WLAN Performance Evaluation

A. Practical Testing environment

The WLAN performance was evaluated for multimedia streaming using the multimedia e-content whose specific characteristics are described in the next section.

The experimental system was comprised of a multimedia streaming server, a content manager, one AP and a laptop computer with a WLAN card. The laptop was used as a client terminal with real-time decoding capability of MPEG-2 streams. The audio and video streams are delivered over RTP/UDP at a bit rate of 2 Mbps and the control functions are implemented over RTSP and RTCP (Wu et al., 2001).

At regularly spaced points along various paths in the intended coverage area, a streaming session was initiated by the client terminal and the received throughput was measured for 2 min. The received radio signal power at the same locations was also measured using a simple radio receiver (i.e. spectrum analyser) coupled to an omni-directional antenna. The results obtained from these two different measurements provide a performance factor of the WLAN streaming services, as discussed in the following subsection.

B: Experimental results

The received radio signal power and the network throughput for two selected paths (1 and 2) are shown in Figures 2 and 3. Path 1 and 2 corresponds to a line of sight (LOS) and non-line of sight (NLOS) scenarios, respectively. Figure 2 shows that along path 1, the throughput is kept almost constant and equals the maximum bit rate of the MPEG-2 streams for all locations. Despite the fact that received power decreases down to –57dBm, the throughput is not affected. This is expected in path 1 because the user laptop is always in LOS and the received power is still well above the minimum threshold. A rather different behaviour is obtained from measurements along path 2, as it can be shown in figure 3. In this case the throughput suffers a significant decrease after point 13, which corresponds to a received power below –75dBm. After this point there are two points (15 and 18) where the measured throughput rises again to its maximum value. Therefore, the reason for the higher throughput at these points is in fact a stronger radio signal.

The subjective *QoS* obtained at the various measurement locations was found to have a strong correlation with the throughput shown in figures 2 and 3. Whenever the total throughput does not reach the laptop, several video frames are skipped by the MPEG-2 decoder, which results in unacceptable loss of information for this type of application. Therefore the minimum received power for an acceptable QoS

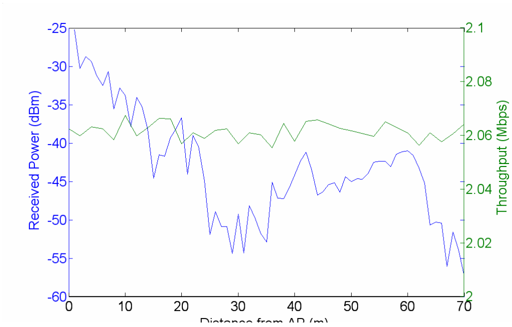

Figure 2: Received power and throughput analysis along path 1.

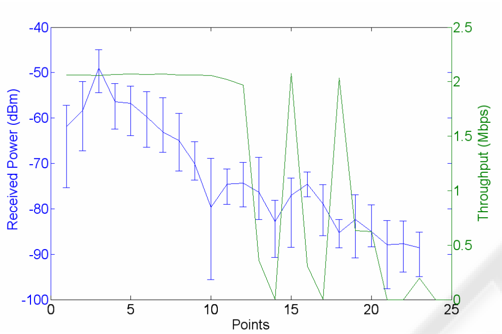

Figure 3: Received power and throughput analysis along path 2.

is approximately about -75dBm. Although this is not an absolute figure, it can be used with a good level of confidence if the WLAN characteristics do not change significantly. Consequently, every access location that did not comply with the minimum received power outlined above was discarded for the purpose of this study. This is of major importance in e-Learning applications because low QoS leads to a harmful contribution to the learning process. A more detailed description of the WLAN performance was recently presented by the authors in (Crespo et al., 2004).

3 PEDAGOGICAL E-CONTENT

The e-learning component of the proposed b-learning model includes multimedia e-content specifically produced for this purpose. Since the application in this work is a module on Electronic Principles, this comprises problem solving methods and examples of electronic circuit's analysis, as described in the next section. Considering the specific characteristics of the communication infrastructure (802.11g wireless LAN), in particular its maximum transmission data rate of 54 Mbps, the option was to use broadband e-content in order to achieve low coding distortion. The e-content produced was of two different types: i) documents with short theoretical basics and proposed problems, i.e. extended tutorial sheets, and ii) compressed digital audiovisual content comprising the lecturer explaining the solving methods employed and solving the proposed problems by using a whiteboard and appropriate markers of different colours. Since the creation, delivery and use of the first type of content is relatively simple, no further reference will be made to it.

In regard to audiovisual content, an important aspect to be considered from a technological point of view is the characterisation in terms of motion and image quality of the visual information. While the first might be important to define the refreshment rate used for pictures (temporal resolution), the second is important for defining the image resolution. Both of them partially define the video signal quality and ought to be taken into account for each type of application, in the light of the service requirements and efficient use of resources (e.g. bandwidth, storage capacity). The higher the spatial-temporal resolution, the more demanding requirements are imposed on information server storage capacity and network bandwidth. Therefore, in order to provide an acceptable video signal quality and not waste resources, it is desirable to adapt the video signal parameters to the application requirements.

The audiovisual information comprises a lecturer speaking, writing on a whiteboard and moving in front of the whiteboard area. Figure 4 shows one picture of the visual content used in this work. From a semantic point of view, this scene contains two visual objects with different semantic value for the human observer: the lecturer and the whiteboard. In regard to subjective quality of this visual scene, it should be pointed out that motion smoothness is more important than texture accuracy in the case of the lecturer, whereas texture is much more important than motion in the case of the whiteboard. However, since in MPEG-2 (ITU-T, 1995) it is not possible to distinguish between areas within the image, the requirement of high spatial detail is dominant because most of the semantic value lies in the whiteboard. Here, is where the lecturer writes down pedagogical content for supporting and complementing the oral explanations, which results in video signals of relatively slow motion and high texture detail *i.e.* characters and diagrams written with a marker. This means that the spatial resolution of the video signal must be high enough in order to be easily understood and to prevent unwanted learning difficult factors arising.

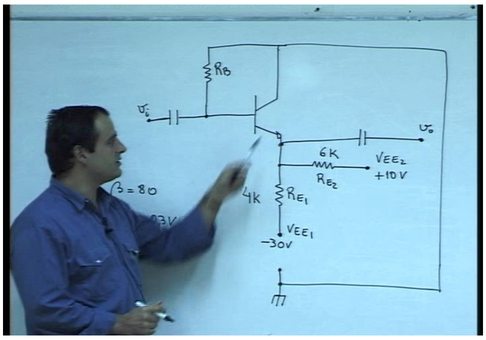

Figure 4: Example of visual content used for e-learning.

3.1 Digital Format and Compression

The audiovisual information is digitally captured and compressed in the standard format MPEG-2 *Main Level@Main Profile,* as defined in the ITU-T Recommendation H.262 (ITU-T, 1995). The video resolution is 720x576@25Hz, 4:2:0 format, which makes this type of e-content fully compatible with several media distribution systems, such as Digital Television (DTV) and Digital Versatile Disk (DVD).

The considerations outlined above with respect to signal quality and resource usage were taken into account to determine an appropriate bandwidth for encoding the audio and video signals. An informal subjective testing was carried out by six lecturers in order to find out the best compromise between the bit rate of compressed streams and the content subjective quality (note that audio and video signal quality is still dependent on the multimedia encoding equipment). Then the minimum acceptable bit rate was found to be 94 and 1816 kbps for audio and video, respectively. This yields a total of about 2 Mbps after multiplexing into an MPEG-2 Programme Stream (ITU-T, 1995). Note that an uncompressed video with the same spatial and temporal resolutions produces a bit rate of 720x576x25x12= 124.416 Mbps and would require 55.9872 GBytes for storing one hour of video. Thus, the need for using a compressed format becomes obvious. Nevertheless, it should be noted that video and audio compression degrades the original signals introducing an increasing distortion with the compression ratio.

To this extent, basic knowledge of audio and video *codecs* characteristics, in addition to their main parameters and implications on the target application, is a requisite for achieving acceptable quality performance. For example, a bit rate between 4 and 6 Mbps is enough to achieve good quality with fast motion video.

3.2 e-Content Creation

In this work, three main requirements were defined for generating e-content: i) the lecturers involved in the process should not need to have any specific technical skills, in order to make e-content creation an easy task, ii) neither should it demand for extra lecturing time effort, so that work overload can be avoided; iii) post-production should not be necessary in order make it cost effective. A similar approach is described in (Schutz et al., 2003).

Two modes of content creation were envisaged in the light of the above requirements. One of these consists in real-time capturing of live classes where the lecturer presents pedagogical content by using the whiteboard and interacts with students. The video camera is always placed at a fixed point, where both the lecturer and the whiteboard are always within the camera visual range and fixed focus might be manually preset. If the whiteboard is too wide so that camera pan is required, then a remotely controlled camera is used with a limited number of preset positions that can be dynamically changed by the lecturer.

The other mode of e-content creation is to setup dedicated recording sessions, where the lecturer acts in front of the whiteboard as in a normal live class. In this case, there are no students inside the classroom, but a cameraman is present to operate the system. A second lecturer is present in the classroom monitoring the session in order to ensure the correctness of the technical contents and to assure that pedagogical guidelines are followed according to predefined rules.

These two modes have different requirements and result in e-content of different characteristics. While the former does not require any technical assistance at all, the latter needs a cameraman during the recording sessions. However, despite the need for extra resources, the latter results in video content with smoother visual transitions and possible zooming of selected areas within the whiteboard, highlighting the most relevant areas. This is not possible to achieve with the former because the audiovisual content acquisition is almost fully automatic.

From a pedagogical point of view, the two modes also provide different results. In the former, the lecturer is within normal classroom context and the session is not specifically oriented for e-content generation. Consequently, the resulting e-content has several non-interesting periods (e.g. some interaction periods between teacher and students) which is indeed counter-productive in e-learning, because they contribute for diverting the learner's focus from the topic under study. This is not the case of the latter e-content generating mode, because it is exclusively produced for e-learning use, hence not only all possible harmful contributions to the learning process are not present, but also special learning enhancement features might be included, such as more emphasis on specific topics that in general students face more difficulties.

In summary, the former method is less resource consuming but also of lower pedagogical quality for e-learning applications, while the latter requires more resources but results in more adequate pedagogical e-content. In this work the two e-content generating modes were tested, but only the latter was used in the context of this paper.

3.3 e-Content Adaptation to Heterogeneous Environments

As it was mentioned before, this type of e-content is easily adapted to broadband applications such as DTV or DVD. However, if either lower bandwidth communication channels or mobile terminals with limited resources are used, then this type of e-content cannot be delivered as it is. Instead, it must be adapted according to the characteristics of the user terminal and access network.

As an example, such an adaptation would be required, when delivering the same e-content to MPEG-4 capable terminals, where audiovisual scenes might be comprised of different objects characterised by their semantic value. In this case, it is possible to transcode MPEG-2 video frames into two MPEG-4 visual objects such that only the whiteboard visual information and the audio are delivered to end users (Santos et al., 2004). Although in a different context, the importance of e-content adaptation was recently addressed in (Wang, 2004).

The main characteristics of the video object "whiteboard" are its relatively slow motion and high texture detail. The slow motion results from the human writing speed on such type of board, whereas high spatial detail is a consequence of its specific visual contents, i.e., characters and diagrams written with a marker. Therefore, the object can be efficiently compressed by reducing the original temporal rates, so that more bits are allocated to encode the texture information and thus enhancing the signal quality. In regard to the "lecturer" object, it should be stressed that motion smoothness is more important than texture accuracy due to its intrinsic nature and semantic value in e-learning context.

This adaptation process by transcoding was objectively tested in order to evaluate the picture quality under a significant transcoding ratio for matching lower bandwidth wireless channels. A video sequence originally encoded at 2Mbps was transcoded into 500 kbps by using two different schemes: i) straightforward transcoding from MPEG-2 to MPEG-2 and from MPEG-2 to MPEG-4, using a single rectangular object and ii) segmentation based transcoding from MPEG-2 video signals into MPEG-4 visual objects (Santos et al., 2004). In the latter case, the inherent characteristics of each visual object were taken into account, as already mentioned. Then, the same bit rate was set for each video object but they were encoded at different temporal rates. The "lecturer" object was encoded at 25Hz whereas the "whiteboard" object was encoded at 6.25Hz. For comparison with the video frames, after decoding the two objects these were combined to form frames again.

As it can be observed in Figure 5, where the Peak Signal to Noise Ratio (PSNR) is used to measure the picture quality, the transcoding scheme yields a good performance when comparing with both references. By using different coding parameters for each video object, the transcoded pictures have better spatial quality in the whiteboard area, mainly because of its reduced temporal rate, which allows more bits to encode the texture. The composition problem that arises when different video objects are displayed at different frame rates may be overcome by filling in the missing areas with pixels from the surrounding area, though this is not addressed in this paper. The same behaviour is obtained for other transcoding ratios, which means that this might be an useful adaptation method for this type of e-content.

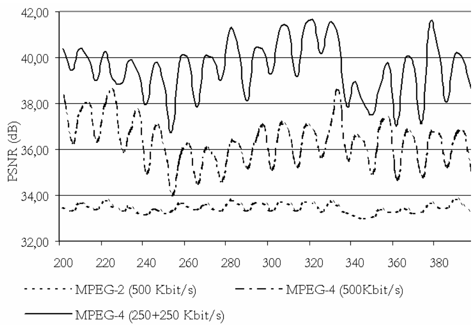

Figure 5: Picture quality obtained after bandwidth adaptation through transcoding.

4 A B-LEARNING APPROACH FOR ELECTRONIC PRINCIPLES

The proposed b-learning process is depicted in Figure 6. This is based on a set of pedagogical strategies with the purpose of creating a flexible learning environment through complementary learner-centred interactions. This pedagogic model also aims at contributing to develop students' self-learning skills, increase their learning independence and possibly achieve financial returns by reducing cost without compromising the learning outcome quality. The different types of interaction that comprise the pedagogic model are provided through different pedagogical agents (Rickel et al., 1997), such as the lecturer in classroom sessions, the portable computer and e-content in e-learning sessions, working group members in collaborative sessions and the lab tutor in practical sessions. The learning outcome, which is the student's ability to deal with electronic circuits including both theoretical knowledge and practical skills, is reached at the end of the whole pedagogical process.

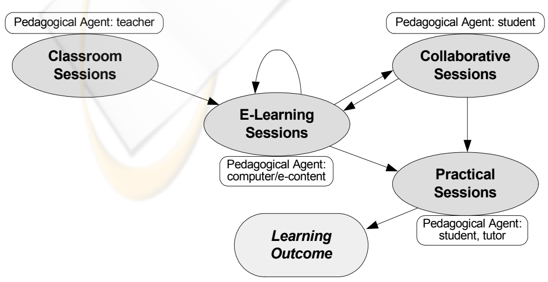

Figure 6: The proposed b-learning model.

4.1 Classroom Sessions

The classroom sessions are based on traditional face-to-face interaction between students and lecturer. The latter acts as the pedagogical agent in this type of learning environment. The theoretical content is presented by the lecturer using the whiteboard and slides as supporting lecturing material. Each topic corresponds to a different chapter in the text book, which may also include related problem solving methods to be applied later in both the e-learning and collaborative sessions. In this type of session, interaction between the lecturer and students is asymmetric, because most of the time is spent by the lecturer delivering knowledge to students. A smaller percentage of the time is spent on questions, answers and critical analysis involving the whole class. Although this may not represent the most favourable operating mode from a pedagogic point of view, in practice it cannot be much different because of the large number of students inside the classroom, particularly in Portuguese scenarios (e.g. sometimes over a hundred students).

4.2 e-Learning Session

The e-learning sessions introduce flexibility in the learning experience and develop student skills and self-awareness of their own learning process. In these sessions students access e-content from a streaming server, through the on-campus wireless network without time or space constraints. The laptop along with e-content act as the pedagogical agent in these type of sessions, where students have the opportunity of attending the recorded sessions to learn problem solving methods, practical aspects related to each particular topic and clarify what they have not fully understood in previous learning sessions. The pedagogical e-content is produced by lecturers with significant teaching experience in the subject such that special emphasis is put on those particular aspects that usually raise more learning difficulties.

4.3 Collaborative Sessions

In collaborative sessions, students are organised in working groups where they join individual efforts to solve proposed problems engaging in a complementary learning experience. The learning outcome is a contribution to improve their knowledge and skills in dealing with different aspects of the topic under study. These sessions may be assisted by a teacher mainly for guiding the students along their own learning process rather than directly teaching them how to get to the final solution. The resulting knowledge should be obtained from the information already available at this stage (in theoretical and e-learning sessions) and its processing within the working group in the form of student-to-student interaction. To this extent, whenever the lecturer is present, he should only help processing the information, offering alternative visions on the same problem in order to favour the development of critical and analytical skills.

4.4 Practical Sessions: Laboratory Work

The last session of the learning process consists of practical work in the Lab, where students compare and analyse the real behaviour of electronic components, circuits and systems studied in previous sessions. This type of session is used to consolidate the knowledge and develop practical skills through experimentation and application of theoretical concepts. As in the collaborative sessions, a tutor might be present for guiding the students in their learning process.

5 ASSESSMENT

The b-learning model was assessed through a student survey where the emphasis was put on the e-learning component, since this constitutes the new component introduced in the existing pedagogical process. A questionnaire, addressing several aspects ranging from the technology in use to the possible contribution of this learning model to increase the success rate, was distributed among undergraduate students on this particular course. The questionnaire was answered by 72 students. All students initially followed the learning guidelines given by the lecturer, but it was observed that some of them have not always strictly followed these, as one would expect.

5.1 Results and Analysis

Analyses of results have shown that the b-learning model was well accepted among students and in some aspects even exceeded the expectations. Remarkably, 22% of the students have classified the wireless e-learning method as excellent, 49% considered it as good, 18% as reasonable and only 11% have doubts if there was any advantage on using it. When asked if their first opinion about the available pedagogical e-content has changed as they used it for learning, 40% of the students answered that it revealed to be better than they initially expected and the remaining ones kept the same opinion as when they first started using the system. None of the students said that it was worse than they initially thought after using it regularly. Regarding the technical point of view, they suggested improvements, essentially on the quality of the sound (42%) and image (24%). In regard to the global quality of the system (sound, image, computer, access and logistic conditions) 53% considered it good, but 42% considered it just reasonable.

At the end of the semester, only 36% of the students have used the system according to the predefined guidelines. The others accessed the e-content only to clarify specific doubts or to catch up with any unattended classes. Figure 7 illustrates these results, which mean that the b-learning model was not strictly followed by all students. Rather than using the available e-content for improving their knowledge through regular e-learning sessions, the students seem to access the system only when they feel it is really necessary.

From a pedagogical point of view, the opinion of 98% of the students is that the e-learning sessions provide significant help in their own learning process and 87% believe that such an e-learning system applied to all course modules would be beneficial for increasing the student success rate. However, when questioned about the possibility of replacing the conventional classes by e-learning sessions the opinion is unanimous: the e-learning session should not substitute traditional classroom sessions. This opinion does not seem to be very consistent with others, since 73% of the students pointed out that an advantage of e-learning sessions is the possibility of establishing their own learning schedule and 87% refer that more flexibility in managing their available time is an advantage. A majority of 72% say that this type of e-learning did not increment significantly the time spent on learning when comparing with the traditional classes.

The results show that students still have some reluctance to engage in new pedagogical methodologies. The knowledge obtained through methodologies that are not strongly dependent of the presence of the lecturer, reveals to be a process that needs to be encouraged and advertised among students.

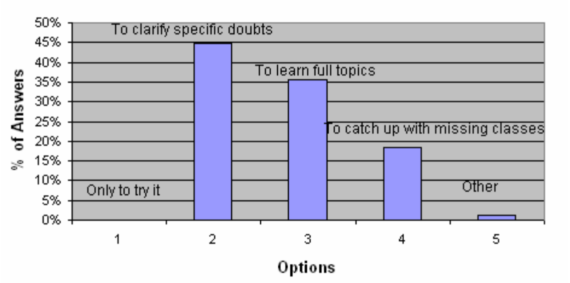

Figure 7: Students main usage of the e-learning system.

6 CONCLUSIONS

A novel b-learning approach supported by mobile technology has been developed and tailored for application in Electrical Engineering education. Blended learning has been tested on an Electronic based subject and results have demonstrated relatively good outcomes when comparing to either a traditional classroom model or one that only embraces online delivery. On the one hand, the approach seemed to be well accepted among students in terms of the available technical resources. On the other hand, student learning outcomes were observed to be somewhat conditioned by their lack of independence and initiative, even though they could access e-content anywhere on campus while on the move. There is a need to respond to changing teaching needs more rapidly than is currently possible. Combination of e-learning and other learning modes were adopted to match the available wireless technology and the availability of lecturers, since the costs of creating an online course may be prohibitive, both at the initial development and in ongoing maintenance. The proposed approach is established and provides a continuing framework for new e-content deliverables within the organisation.

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