Int. J. Engng Ed. Vol. 20, No. 1, pp. 31–38, 2004
Printed in Great Britain.

0949-149X/91 $3.00+0.00

Semi-distance Learning vs. Traditional Organisation for a Master's Degree in Electronic Engineering: An Experience at the Technical University of Catalonia (UPC), Spain*

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This paper describes a semi-distance learning method applied to a technical degree which requires a significant amount of laboratory work. Their aim is to achieve for students that combine professional activities with scholarship a similar level of theoretical and experimental training to full-time students while reducing their physical presence at the university. Another objective is to reach a success rate for this kind of student comparable to the rate obtained by other full-time students. The methodology for this academic project is described, as well as their implementation in several subjects. The whole experience is evaluated and compared with the traditional organisation.

INTRODUCTION

CURRENT DEVELOPMENTS in knowledge innovation mean that constant retraining through one's professional life is needed. The development of learning strategies that allow professionals to combine work and study will be of key importance in the near future [1]. The School of Telecommunication Engineering of Barcelona (ETSETB) of the Technical University of Catalonia (UPC), being aware of the strategic role of these learning methods, offers the Degree in Electronic Engineering in semi-distance format.

In Spain, the Degree in Electronic Engineering is a *second-cycle* (2-year) degree. Students holding a *first-cycle qualification* (usually a 3-year course) in electronics-related areas such as communications, industrial electronics, telematics, etc., are allowed to enrol. It is equivalent to a conventional master's degree in some countries [2]. This degree takes full-time students two years to complete the courses. It includes subjects on electronic and photonic devices, microelectronics, digital systems, electronic instrumentation and measurements, computer theory and design, microwaves, economics, and others. Table 1 shows the courses included in this degree, indicating the number of hours in the lecture room and in the laboratories for each one. The studies are organised in semesters. Because of the high technical specialisation, students will need to spend about 600 hours carrying out experimental work in the laboratories, which means an average of 2 hours per school day over 2 years.

Because *first-cycle* qualifications provide professional competence, most students combine professional work with scholarship. This twofold activity makes it difficult for them to follow conventional studies which are designed for full-time students. This extra load caused by the twofold activity represented in September 2000 an increment of the time required to finish the studies (6.5 semesters instead of the 4 semesters planned), but it only had a slight influence in the dropout rate which always has been about 12%. The cyclic structure of teaching in Europe forecast in The Bologna Declaration [3–4] may lead to a generalisation of this situation in the near future.

To cater for this type of student, a methodology based on distance learning might seem ideal. This type of methodology was introduced at universities more than a century ago [5], but it had a very limited effectiveness primarily due to the isolation of students, which led to high dropout rates. The

* Accepted 23 September 2003.

Table 1. Electronic engineering subjects (theory hours mean hours spent in the classroom; students can choose optional subjects from several sets of subjects offered by the ETSETB)

Courses	Theory hours	Lab. hours	Total hours
Electronic Instrumentation (4A)	30	30	60
Electronic and Photonic Devices I (4A)	60	–	60
High Frequency Circuits (4A)	45	–	45
Electronic Equipment (4A)	30	30	60
Electronic Control Systems (4A)	30	15	45
Business Administration (4A)	45	–	45
Electronic and Photonic Devices II	45	15	60
Microelectronics I	30	30	60
Microelectronics II	30	30	60
Digital Systems I	30	30	60
Digital Systems II	30	30	60
Electronic Engineering Applications I (Sensors and Signal Conditioning)	30	30	60
Electronic Engineering Applications II (Power Electronics)	30	30	60
Computer Architecture and Operating Systems	45	30	75
Communications Networks, Systems and Services	60	–	60
Signal Processing and Communication	60	–	60
Telematics Laboratory	–	30	30
Optional subjects			390
Final Project			150
Total			1500

situation of this type of teaching has changed considerably in the last decade of the 20th century, when new information and communication technologies have broken this isolation and have allowed an effective interaction between teachers, students and their classmates without them needing to be physically present [6–9].

However, in the case of engineering students, there is an additional issue that has not yet been resolved: the experimental training of students in a laboratory. There is widespread agreement across the university community on the importance of experimental training in Engineering [10–13]. The importance of this issue is reflected in the syllabus (Table 1), which allocates 40% of its duration to learning in a laboratory setting. To provide this training within a distance methodology, a wide variety of proposals have been put forward [14–18], although, in our opinion, none of these are completely satisfactory.

One of the proposals involves carrying out all the practicals on-site at the University's laboratories over a period of few days. The intensive nature of this proposal impedes the in-depth exploration of concepts and procedures, which tend to require an unhurried pace. A second option is to tailor the experimental training to individual students, by making use of the installations and equipment belonging to the industries in which they work. It would be difficult to extrapolate this option to a great number of students and it might exclude experimental training in a wide variety of technological areas. A third possibility is to substitute sessions in laboratories for computer simulation. This option impedes the students' access to fundamental aspects of experimental training in a laboratory, such as setting up real experiments and all the problems associated with experimentation in the real world, which is particularly important in Electronic Engineering. Another option is for the students to buy laboratory kits and carry out the experiments at home. This alternative is obviously only viable for simple experiments using very basic measuring equipment. Finally, another option is to carry out the experiments at the University's laboratories by remote control using the Internet. This option has been introduced in recent years, although its scope is limited and it is difficult to apply to all the laboratories. It is also possible to find Engineering courses which obviate the need for experimental activity, although, in our opinion, the training provided would be of an inferior quality to that obtained by students receiving on-site training.

UPC chose to develop a semi-distance method in order to extend the availability of the Electronic Engineering degree to those students that simultaneously undertaking a professional career. The aim of this semi-distance format is to achieve for its students a similar level of theoretical and experimental training to full-time students, while reducing their physical presence at the university. At the same time, we aim to take full advantage of the possibilities of interaction offered by new technologies in order to stimulate the learning process and reduce the student dropout rate that often characterises the purely distance-education system [19]. As an example, the ratio between the number of graduates and the number of students enrolled on Industrial Engineering courses at all public Spanish universities was 0.088 in the year 1997/98, whilst the same ratio for the UNED (the Spanish university for distance education) for the same courses was only 0.013, that is to say, a figure six times smaller [20].

The semi-distance format began in September 2000, and two subjects were offered in the semi-distance format for the first time. Presently, the whole Master is offered in semi-distance modality [21]. Both the semi-distance and contact formats are running simultaneously. In this initial stage, all the laboratory classes require the student to be physically present, whilst theory classes follow a distance-learning methodology. In the near future, we expect to reduce the need for the physical presence of students in laboratories by making a more intensive use of simulation and remote access to the laboratories. Nevertheless, we believe that a significant presence of students in the University's laboratories will continue to be important in order to ensure the quality of their training.

This semi-distance format is based on a method that differs from the conventional education system. The generic elements used are described in the text section and then, their implementation in some courses. Results obtained with this methodology are discussed later and, finally some conclusions are drawn.

METHOD FOR SEMI-DISTANCE LEARNING IN ELECTRONIC ENGINEERING

The challenge of semi-distance students achieving a similar level of training and success rate to their full-time counterparts stimulated co-operation between the lecturers of the Department of Electronic Engineering and the experts of the Institute for Learning and Teaching (ICE) at UPC [22]. The aim of this collaboration was to design specific tools for this academic project [23–24]. These specific tools are described in the following paragraphs.

- *Course Study Guide*. Semi-distance students, who combine professional careers and scholarship, must be able to organise their own time. The risk of having complete freedom is that students can often leave their studies to one side for long periods, making it difficult to learn effectively. The solution here was to divide the total course duration into *modules*, each lasting 3–4 weeks. Students have complete organisational freedom within a module, but results are expected within its deadline. This varies among courses: it could, for example, be a contact session or to deliver an exercise collection, but particular results are still expected before a specific date. The *Study Guide* is a document that contains a detailed description of tasks involved (study of theoretical concepts, exercises, self-evaluation tests, etc.) for each module, with an indication of the duration of each activity, but no specific timeline.
- *Study material for semi-distance learning*. Students must be able to follow the subjects without the presence of a lecturer. They need didactic material that substitutes the notes that conventional students take in the classroom. It must be self-contained, including theory, exercises and self-evaluation tests. For some courses specific 'textbooks' have been written. For others, already existing texts which were specifically developed for the subject are used.
- *Experimental training*. Laboratory activities are an important part of the Electronic Engineering syllabus, and constitute about 40% of the total load. These activities must therefore not be eliminated nor reduced in the new system. Special timetables are used, with laboratory sessions in the late evenings in order to facilitate students' attendance. This contact activity is also positive in that the students interact with the lecturing staff and other students, thus alleviating the feeling of isolation that is typical of distance learning education.
- *Collaborative group work*. The feeling of isolation in traditional distance learning education is one of the factors that accounts for the high percentage of student dropouts. In order to address this problem, collaborative learning is stimulated. Group work is the natural way of working in laboratories, and it is also encouraged for other activities, such as problem solving, small projects, etc.
- *Evaluation and grading plan*. The aim of the evaluation and grading plan is to ensure that students reach the learning goals set by the program. It is also used in order to constantly stimulate the evolution of the learning activities during the semester. The evaluation plan must also achieve another goal: it should help students periodically perceive that their investment in the learning process is worthwhile, and that following the *Study Guide* is the best way to ensure success in the course.
- *Internet as a communication tool*. As these students learn from home, good communication between them and the lecturers is essential. UPC has developed a digital campus called eATENEA on a generic platform, which enables this bi-directional communication, allowing the creation of intranets for each of the courses. The Digital Campus is accessible using Internet browsers such as Netscape Communicator 4.5 or Internet Explorer 4.0, and has different user profiles for students and lecturers. Each of these profiles allows different work modes: agenda definition, interchange of documents, creation and undertaking of assignments, exercises and projects, access to a list of students, group notifications, e-mail, discussion groups, etc. [25].

APPLICATION OF THE SEMI-DISTANCE METHOD

In this section, the specific use of the tools described above in some representative courses with different intrinsic characteristics will be discussed. The courses selected include Electronic and Photonic Devices, which involves no laboratory work. Microelectronic Design, where laboratory work is based on simulation tools, which could allow students to carry out most of the lab work at home, Sensors and Signal Conditioning, which is based on experimental work in laboratory (although part of it could be done from home over the Internet), and Electronic Instrumentation, which has a lab work program necessarily involving the use of the instruments in the lab, although there are plans to allow this use remotely over the Internet.

- *Electronic and Photonic Devices.* This is a theory-based subject which has traditionally been perceived as highly difficult by the students. Learning this subject demands unhurried and constant work. For this reason, the most important goal in designing the course plan was to stimulate this kind of work. In order to achieve it, emphasis was placed on the *Study Guide* and the evaluation plan. The course is organised into four modules. Each module is composed of a set of study and self-evaluation activities, and specific module work that must be submitted. A specific textbook has been developed for this semi-distance subject [26], which contains the theory, exercises, problems and self-evaluation activities. At the end of each module there is a contact activity for about 2 hours, devoted to reviewing the module work, and performing an evaluation exercise.
- *Microelectronic Design.* This course includes both theory and laboratory work. For the theoretical part, new study material has been developed for semi-distance students. This material is mainly in the form of an interactive book, designed for self-learning, which also is in itself the study guide of the subject [27]. It is distributed in PDF format and relies heavily on the interactive capability of this format. The book includes questions and problems, the solutions for which are not provided until the student has correctly solved them. It also includes links to web pages and to an external electronic simulator. Despite the fact the experimental learning is now carried out in contact with the tutors in the laboratories, it is suitable for work at home, because the material needed to follow the experimental part of the subject are not very restrictive.
- *Sensors and Signal Conditioning*. The subject is dedicated to practical design in electronic engineering, using sensors and conditioning circuits as case studies. Students have to solve small design problems using real sensors and electronic component specifications. The subject is based on a textbook [28] not specifically developed for distance learning, a problems book and the laboratory manual, plus additional support material that is accessible via the website. The study guide gives an exhaustive schedule, specifying the study activities, the practical work and the reports the students should submit at the end of each module. The learning method is based on the entrapment of the students using the deliverables. Several problems should be submitted at the end of the module, and a preliminary work should be completed in preparation for the lab projects study. Direct contact with the students in the lab sessions has proved to be a good way to ensure their commitment, resulting in a very low dropout rate. The lab work is based on guided designs. Each session involves a specific project (e.g., a thermometer, scale, pH-meter . . .) with specifications derived from a practical application. In order to reduce the number of contact sessions, new distance lab sessions are being designed in which students perform remote calibrations of smart sensors using the new standard IEEE 1451.2 [29].
- *Electronic Instrumentation*. For full-time students, one half of the course load is on the labs, and the other half is in the classroom. The same lab load is applied to semi-distance students. The course is essentially devoted to uncertainty assessment applied to programmable instrumentation systems, including interconnection problems. Because the lab activities are based on the use of specific, expensive, instruments, it is unlikely that the students can carry out those activities at home. However a pilot experience is being tested for them to remotely access the instruments via the Internet. The course is divided into four modules. Specific textbooks developed for the course are used [30, 31], although they were not developed for distance learning. The *Study Guide* includes self-evaluation exercises and a detailed explanation on how to use the textbooks and other additional material.

RESULTS

The master degree in Electronic Engineering at the UPC has a high prestige in our country. An indicator of this prestige is the number of students who would like to enrol these studies. For example, in September 2002, 116 students applied for 52 places, a very high number if one takes into account that three other universities in the metropolitan area of Barcelona also offer the same degree.

The assessment of a teaching method is a complex task that covers issues as diverse as the satisfaction of the teacher, the student and society in general, as well as taking into account training, economic and social factors [32]. This task goes beyond the objectives of this essay. We will carry out a comparison between on-site teaching and distance-learning formats with exclusive reference to student satisfaction and academic output because those participating in both of these modalities have achieved the same level of competence having followed identical theoretical and practical contents and passed the same evaluation tests.

Typically, students who opt for a semi-distance modality take three subjects simultaneously, two of which involve laboratory classes. Therefore, students attend two laboratory classes a week (each one lasting two hours) and work at half the

Table 2. Average number of students enrolled on a semi-distance course (the same figure for conventional contact students is shown in brackets; the average number is calculated adding the number of students enrolled in each subject of each course (4A, rest of courses) and dividing into the number of subjects of the course considered)

	Autumn 2000 Semester	Spring 2001 Semester	Autumn 2001 Semester	Spring 2002 Semester	Autumn 2002 Semester
Course 4A	12 (46)	20 (48)	30 (32)	33 (21)	32 (39)
Rest of courses	–	5 (44)	23 (17)	18 (18)	18 (20)

Table 3. Average success rate of students enrolled on semi-distance course (the figure for conventional contact students is shown in brackets)

	Autumn 2000 Semester	Spring 2001 Semester	Autumn 2001 Semester	Spring 2002 Semester
Course 4A	61% (66%)	61% (45%)	41% (81%)	55% (77%)
Rest of courses	–	100% (82%)	74% (71%)	75% (92%)

pace of conventional students, which means that the total duration of the degree is about four years.

In order to assess the semi-distance method presented in the sections above four indicators will be analysed: the evolution of the students taking this modality, the success rate of these students compared with that of full-time students, the total success rate when the semi-distance modality has been introduced, and students' answers to a questionnaire conducted by UPC.

Table 2 shows the number of students enrolled on the semi-distance format since it was introduced in September 2000. Students that start the program must take first semester (called 4A) subjects. After that, they are free to take subjects in any order, the only restriction being the specific prerequisites in some of them. Because not all the courses on the program had been offered in semi-distance format, the school allowed students to choose a traditional or semi-distance format for each subject. Because of this, the figures in Table 2 are representative of the actual demand and interest of the students for this format. Note that the number of semi-distance students enrolled is similar than full-time students.

Table 3 shows the percentage of students that passed the courses over the total enrolled. The same figure for full-time students is also presented. The figures of semi-distance modality are slightly lower than for contact format. In general the success rate is lower for 4A courses, since a significant number of students enrol on the program straight after passing the first-cycle of their degree and then drop out when they find a job. However, these figures are much higher than usual for distance learning institutions in our country. The low success rate in 4A courses for autumn 2001 is due to adaptation problems of lecturers and students to the new semi-distance format. The method presented above for the semi-distance format has proved to yield a high success rate, but it introduces important changes in relation to traditional methods used in contact learning. An adaptation period is needed in order to assimilate it, and when many courses are introduced for the first time in the new format

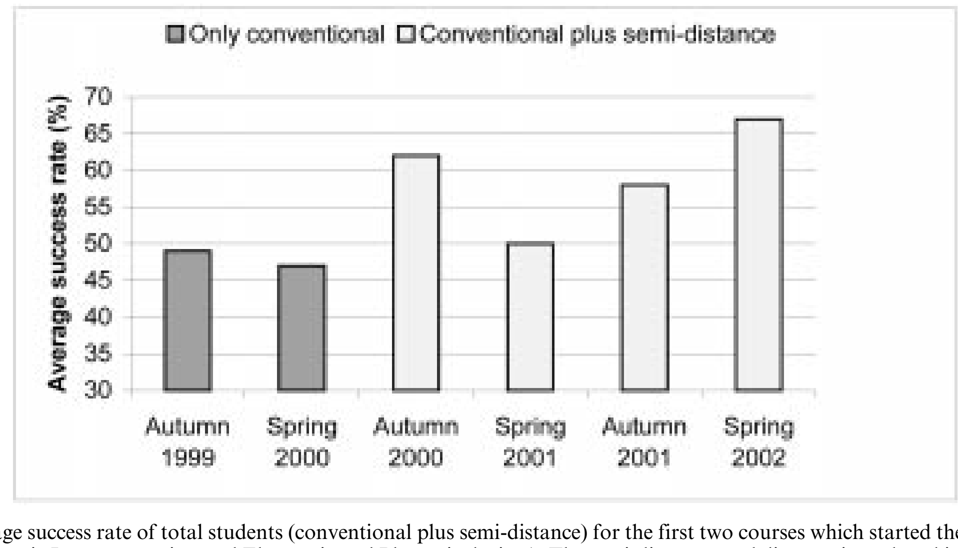

Fig. 1. Average success rate of total students (conventional plus semi-distance) for the first two courses which started the semi-distance format (Electronic Instrumentation and Electronic and Photonic devices). The semi-distance modality was introduced in Autumn 2000 semester.

Table 4. Sample of the average value of the answers of the semi-distance students to some questions in the university poll (each sentence is graded by the student from 1 to 5 based on their agreement with what it is expressed; the poll was answered by 70% of the students enrolled in semi-distance format)

Questions in the student's poll	Average value
The work plan for this subject is appropriate	3.8
The schedule in the subject guide is realistic	3.5
The didactic material for the semi-distance learning of this subject is appropriate	4.2
Communication with the professor through the Digital Campus for solving doubts has been easy in this subject	4.3
The overall assessment of the semi-distance learning in this subject has been positive	4.2

these adaptation problems can have a significant effect.

Another issue that may be relevant when assessing the introduction of the semi-distance modality is to value whether its introduction has meant a higher success rate for the total number of students enrolled in the subject. Figure 1 presents the overall success rate (total number of students enrolled for both modalities) in Electronic Instrumentation and Electronic and Photonic Devices, the two subjects for which the semi-distance modality was introduced in autumn 2000. Although there are few figures on which to base a definite conclusion, they do seem to indicate that the introduction of the semi-distance modality has led to a higher pass rate, which means that this modality helps this kind of student to progress in their career.

Finally, Table 4 shows the students' answers to some of the questions from the questionnaire conducted by UPC. The questionnaire is based on sentences that students grade from 1 to 5 according to the extent to which they agree with what is expressed. An answer of 3 means they feel neutral. Usually, the average results obtained with full-time students in our School range from 3 to 3.5. The figures obtained with semi-distance students show that they are satisfied with the semi-distance modality.

CONCLUSIONS

The semi-distance format described here allows students to combine scholarship and professional work in an advanced technical degree. The high demand for this format is an indicator of the interest and need by students and society in general for this kind of solution. The method developed allows students to achieve a similar training level to full-time students in theoretical and experimental instruction, and yields a notable success rate, comparable to that obtained for full-time students. This success rate is higher than that typically achieved by other distance learning higher education institutions in our country. Obviously, the time required to finish the degree is about double for the semi-distance students than for full-time ones.

Acknowledgements—The authors would like to thank Sara Lopez-Selga of the Instituto de Ciencias de la Educación for her collaboration in the search for and analysis of experiences of semi-distance education in the field of engineering.

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