

Collaborative Projects Involving Industry and Academia to Enhance Electrical Engineering Education: The Perspective of three Portuguese Higher Education Institutions at the Master Degree Level

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Abstract— In this paper, Electrical Engineering Education at the Master level is presented through three perspectives of collaborative projects involving industry and academia. The presented perspectives originate from three Portuguese Higher Education Institutions representing the University, Military Academy and Polytechnic School viewpoints. Throughout the presented projects, an increasing student motivation was observed, driven by the practical experience provided through the industrial sector approach. This cooperation also generates opportunities to develop new perspectives and ideas for follow-on projects as well as innovative academic publications.

Keywords— Collaboration between Academia and Industry, Electrical Engineering Education, Industry Internship, Master's Degree Level, Projects

I. INTRODUCTION

Modern world societies require fast and effective development of the different areas of our life especially and moreover the technological ones. One way to meet new challenges is to incentivise the students to prepare their projects/dissertations in the industry or get an internship, namely abroad. It contributes to the improvement of engineering education at large scale. The collaboration between academia and industry produces interesting outcomes, bringing effective improvements into electrical engineering education, particularly at the Master's degree level [1].

The continued globalisation of manufacturing and service delivery has led to a concomitant globalization of the

engineering profession. Engineers are increasingly engaged in international projects, including service in multinational teams at different points around the globe, collaborating in a real-time common project using electronic communication. Effective collaboration requires not only the ability of participants to communicate in a common language, but also the assurance of a common level of technical understanding. Such issues are not trivial, given the global diversity of systems for educating engineers, for different goals and skills and for the quality control of their education. From the engineering perspective, the dissertations in an industrial environment or the internships are vital in order to integrate the students in the modern and international engineering world, namely if the internship is abroad [2], [3].

An interesting internship is a new, very good and exciting experience for students. Mostly everyone has more responsibility during their internship than they expected and has more work than predicted. After an internship all the students reflect its positive aspects of this experience: the diversity of work that they have done; the first contact with the professional life; a creative opportunity.

During an internship from the first day, the students will be totally immersed in their work as they will develop their skills in a known company. Generally, there are also lots of opportunities to run their own challenging and rewarding projects. The students can learn from some of the most experienced people in the business to develop their flair and knowledge in innovative culture and develop a network of

like-minded interns and professionals. These approaches facilitate and encourage learning as well as social interaction, reinforcing the understanding of previously studied subjects.

The described collaborative projects share the aim of enhancing the learning experience of students and the creation and dissemination of applied engineering knowledge, contributing for the generation of high value in industry and institutions, while pursuing the qualification of individuals with a high level of scientific, technical and cultural education.

The three degree programs objectives, competences, structure and organization, follow the Portuguese Law, the main principles of the Bologna Process and the recommendations from national and international professional organizations. However, given the different historical backgrounds, engineering education cultures and specific missions and objectives, three different Master profiles are established, which are described in this paper.

II. HIGHER EDUCATION SYSTEM IN PORTUGAL

From the late 1970s Portugal has a binary Higher Education (HE) system, with Universities and Polytechnics. In March 2006 the government published the long awaited law reforming the Portuguese HE degree system in accordance with the Bologna process, introducing namely the ECTS crediting system. The new three-cycle degree system is [4]:

1. *Licenciatura* of a duration of 3 years of full-time study (180 ECTS), offered both by Universities and Polytechnics;
2. *Mestrado* (M.Sc.), of a 2 year duration (120 ECTS), of which at least 35% (42 ECTS) are dedicated to work on a dissertation/project/internship. The *Mestrado* can be conferred both by Universities and Polytechnics, subject to the requirement that the institutions are engaged in R&D activities in the area of speciality.
3. *Doutoramento* (Ph.D.), of which the first year can consist of course modules. The *Doutoramento* can only be conferred by Universities, subject to the requirement that the institutions have a consistent and high-quality R&D track-record in the area of speciality.

The law allows also Universities, not Polytechnics, to offer *Integrated Master* programs of 300 ECTS, in areas where, according to EU rules or to established tradition in the EU, access to a profession requires such a length of studies. That is the case in Medicine, Architecture and in the more traditional Engineering areas [4].

III. MILITARY ACADEMY

The mission of the Military Academy (*Academia Militar*, AM) states that it is a higher education military establishment that pursues teaching, research and community support activities, with the core objective of educating officers for the permanent staff and services of the Army and National Guard. The Military Academy offers six years integrated master degrees, within the Bologna Framework, including the Military Electrical Engineering Master with two profiles: Telecommunications and a Computer Science specialization programmes. The first four years are completed in the Military Academy, being the first year dedicated to the acquisition of military skills, whereas in the last two years, the students

(*cadetes*), complete their courses in *Instituto Superior Técnico* (IST), in the frame of a protocol between the two institutions. The Master thesis must focus on subjects with military application and is usually supervised by a professor from the Military Academy and a professor from IST.

About three/four weeks after the thesis submission there is a public discussion of the dissertation (oral exam) in front of a jury with three professors (two professors from IST and AM and a third one from a different University or Department or a specialist from the industry).

The oral exam has 60 minutes of duration. The student has 20 minutes to present his/her work (usually a PowerPoint presentation with a demonstration of the piece of equipment or prototype developed). Afterwards, the external examiner has 20 minutes to inquire the student and finally 10 minutes for each of the remaining members of the jury. At the end of the oral exam, the student gets a final assessment in a scale of 0-20 values (being 10 the minimum grade for approval).

Two examples of thesis developed in 2013, are shown in figures 1 to 4. In Fig. 1, a new planar integrated antenna with a configurable radiation pattern beam, was developed, using genetic algorithms, to establish communication between the unit and an autonomous surveillance robot [5]. The antenna was designed, constructed and tested using the anechoic chamber at IST. In Fig. 2, the 3D radiation pattern of the antenna is shown.

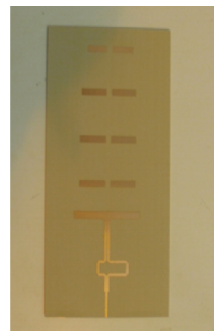


Fig. 1 Planar antenna

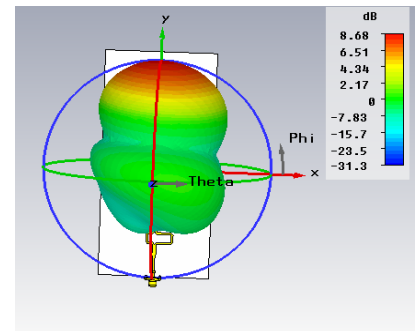


Fig. 2 3D radiation diagram of the antenna

In another Master thesis [6], a crossed dipole antenna was also designed, constructed with a collaboration from EID, a company involved in research for military applications, and tested afterwards. This antenna provides NVIS communication, in the HF band, allowing communications in scenarios with rugged terrain and steep mountains as is the case in Kosovo and Afghanistan, with low cost and simple set-up procedures. The radiation pattern for three frequencies of operation and the antenna configuration are presented in Fig. 3 and Fig. 4, respectively.

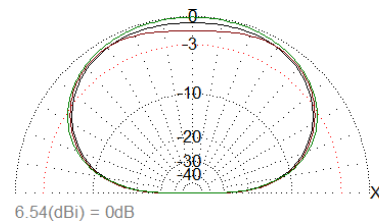


Fig. 3. Vertical radiation diagram of the NVIS antenna



Fig.4 Configuration of the NVIS antenna

After the completion of the Master's thesis, the students are sent to specialized headquarters "Escola Prática de Transmissões", where they acquire hands-on experience with the different equipments used in military transmissions and software developments such as a Cisco certificate.

IV. FACULTY OF ENGINEERING OF THE UNIVERSITY OF PORTO

The Faculty of Engineering of the University of Porto (FEUP) offers an Integrated Master in Electrical and Computer Engineering that lasts five years and is organized in three major specialization areas: Telecommunications, Automation and Energy. After the completion of the first three years of the course (180 ECTS) a diploma in Electrical and Computer Engineering Sciences will be awarded.

The dissertation and/or the internship were introduced at FEUP with the Bologna reform in 2006. At FEUP the students are very motivated for dissertation developed in an industrial environment or internship work. The students work very hard during this period. A significant problem is to get enough projects in industrial environment or internships for all the students (approximately 500 students).

In projects in the industrial environment or in an internship, there are two supervisors, one from the Faculty and another one from the industrial partner. The internship abroad is an opportunity to the promotion of EU-wide mobility of engineers in accordance with the Directive 2005/36/EC on the recognition of professional qualifications [7].

At FEUP, around 40% of dissertations/internships are undertaken in companies and within mobility programmes, around 4%, mainly within the ERASMUS Programme. With the internships students can also gain practical experience, foreign language skills and cross-cultural competences if the internship takes place abroad. One of the difficulties associated with internships is that the number of grants available is very limited. The students understand that many doors are open on account of an internship; this is the reason why internships have a great demand. This facilitates and encourages learning as well as social interaction.

During the completion of the dissertation the student has to prepare a webpage (Fig. 5) for the dissertation that must include: student CV, student motivation for that dissertation/internship, bibliography, main objectives of the dissertation/internship, work planning, weekly reports about the work done and dissertation structure.

The dissertation/internship webpage is periodically checked by the supervisor to monitor the work that the student is carrying out. When the dissertation/internship is completed, the student introduces the written document in the webpage. The quality of the webpage will be considered in the final assessment of this subject. Typically, the duration of the dissertation is 15 weeks (from March to June) and the workload is equivalent to 30 ECTS [8].

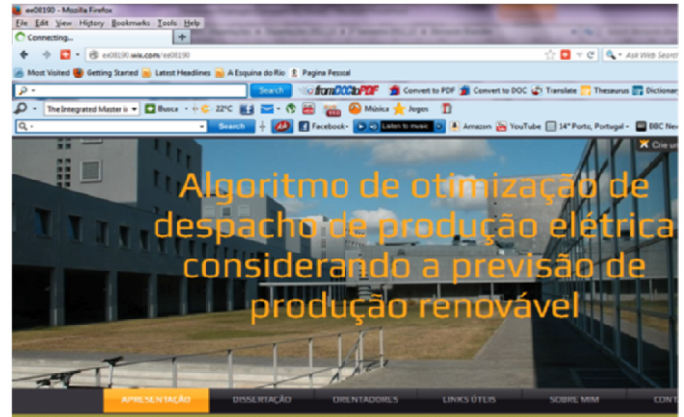


Fig. 5 Example of dissertation/internship webpage

When the internship is finished, the student has to complete the writing of the dissertation. About three/four weeks after the thesis submission there is a public discussion of the dissertation (oral exam) in front of a jury with three professors (two professors from FEUP and a third one from a different University) and a professional from the industry that has oriented the student during the internship in the company.

For the evaluation of the dissertation/internship the jury takes the following valuation factors into account:

TABLE I
JURY'S VALUATION FACTORS

Evaluation of Dissertation (written document)	Evaluation of public presentation
<ul style="list-style-type: none"> Overall assessment of the work Autonomy of the student Difficulty of the proposed work Depth of the work done Relevance/impact in the institution of the obtained results Quality work and produced volume Integration in working groups 	<ul style="list-style-type: none"> Presentation of the work and outcomes Organisation and the content of the presentation Professionalism and posture Thesis Discussion Degree of security and confidence in the given answer Demonstrated level of expertise

The oral exam has a duration of 45 minutes. The student has 15 minutes to present his/her work (generally a PowerPoint presentation is prepared by students). Afterwards the external professor has 15 minutes to inquire the student and the student has the same time to answer the questions. At the end of the oral exam, the student gets a final assessment for the dissertation/internship in a scale of 0-20 values.

The final assessment of the master is a weighted average of the assessments obtained in each subject weighed by the course ECTS. As the dissertation/internship subject has 30 ECTS, for the final Master's classification, this classification is very important.

V. COIMBRA INSTITUTE OF ENGINEERING

The Coimbra Institute of Engineering (IPC/ISEC) Master degree integrates the Automation, Energy Systems and Communication areas in a coherent framework, to create a study profile specially oriented to the present development needs of the industry and organizations. Two transversal Specialization Areas in the electrical engineering domain were established, sharing a partial common structure: “Energy and Automation Systems” and “Industrial Systems” [9].

The Master in Automation and Communications in Energy Systems is composed of a Specialization Course, which has a set of course units representing 55% (66 ECTS) of the total number of credits (120 ECTS), and an Industry Internship, or an original Project, that represents 45% (54 ECTS) of the total credits. It has a highly industry oriented profile, and an after-work schedule. It targets competences in the production, distribution and management of energy as well as in integrated automation and communication solutions in the industry and organizations. Table II shows the profiles and competences of the two specialization areas.

TABLE II
PROFILES AND COMPETENCES OF SPECIALIZATION AREAS

Energy and Automation Systems	Industrial Systems
<ul style="list-style-type: none"> • Targets competences in the production, distribution and management of energy, allowing the analysis and intervention in electrical and renewable energy systems • Specialized courses on: <ul style="list-style-type: none"> – Energy systems supervision and control – Renewable energies – Environmental management – Electrical vehicles – Energy markets 	<ul style="list-style-type: none"> • Targets competences for integrated automation and communication solutions in the industry and organizations • Specialized courses on: <ul style="list-style-type: none"> – Robotic systems – Industrial networks – Integration of industrial systems – Mobility and wireless communications – Industrial computer vision and multimedia

The evaluation of the project/internship includes an informal distributed component resulting from the meetings between all involved persons. It also includes a progress report when planned and the public oral presentation and discussion of the project work or the internship report in the presence of a jury with three professors (two professors from IPC/ISEC and third one from a different Polytechnic or University or a specialist from the industry). This presentation is performed according to the master regulation document. The evaluation is defined by the jury considering at least the following aspects: quality of the technical and scientific contents, quality of the presented document, quality of the presentation and ability to discuss arguments and the contribution of the work to the company, school and society.

The oral exam has 90 minutes of duration. The student has 20 minutes to present his/her work (usually a PowerPoint or Prezi presentation). Afterwards, the external examiner has 40 minutes to inquire the student and finally there are 30 minutes for the remaining members of the jury. At the end of the oral exam, the student gets a final assessment in a scale of 0-20 values.

In five completed editions of the master (2008-2013), about 30 internships and 40 projects have been organized, involving

close industry collaboration and successfully grabbing many applied research opportunities. Projects and internships included collaborations with very representative Portuguese and multinational companies such as Siemens, Refer Telecom and the Portuguese Electricity Company (EDP).

VI. DISCUSSION AND CONCLUSIONS

Projects, whenever possible, should be developed under a cooperation agreement with an industry partner or with an institution. On the other hand, the internships allow the students to be integrated in an industrial or company environment, where he/she will have the opportunity to apply the knowledge and techniques learned in the academic course, as well as to work in teams and to envisage a professional career. The ability to design, fabricate and test, providing hands-on experience is very valued by the students and is the essential part of the engineering paradigm.

Nowadays, projects in an industrial environment or internships are a reality and students are very motivated to engage on them. The number of students asking for projects in an industrial environment or internships is growing every year. Most of the students are of the opinion that the internship is a good opportunity to get relevant experience and if possible go abroad, but it is difficult to get enough scholarships for all interested students.

After projects in an industrial environment or an internship, many students get a job in a company. Some interns find permanent, paid employment with the organisations where they served as interns. This can be also a significant benefit to the employer as experienced interns often need little or no training when they begin their regular employment. Unlike a trainee programme, however, employment at the completion of a dissertation or a project or an internship is not guaranteed.

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