

An Approach to Foster Engineering Skills at Graduation Level: Meeting the Industry Needs

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Abstract—This paper describes a Group Problem Solving approach used for Electrical and Telecommunication engineering graduation students, to foster technical and personal skills while overcoming the consequences on the reduction on courses duration, due to the Bologna agreement format. The approach is described; success experiences and results are discussed.

Index Terms—Active learning, co-operation with industry; engineering problem solving; skills development.

I. INTRODUCTION

The offer for engineering courses in Portugal is mainly concentrated on public Higher Education institutions, which can be of two types: Universities and Polytechnics. Before the adoption of the Bologna declaration format (in the academic year 2005/2006), Polytechnic institutions offered bi-stage courses: 3-year degree and a 2-year superseding course, both with a balance on theoretical and practical issues but focusing on applications. When concluding the first course (3-years) students had the “bacharelato” diploma and could apply for a job as Technical Engineers; upon accomplishment of the 2-year course students obtained the “licenciatura” diploma, which was legally equivalent to the 5-year courses of Universities, and then they could apply for an Engineer Job. Alternatively, after the 5-year period, they could also apply for MSc courses (2-year duration) and to PhD degrees (lasting normally 3-years).

The Bologna agreement imposed modifications and because of that, some challenges arose for all courses and for engineering courses in particular. The major modifications for engineering courses are the ECTS system and the mobility of students. However, the big challenge was the shortening on the course duration at the bachelor level, which currently last in general 3-years (180 ECTS). Because of that time reduction, while some matters and issues prevailed, some others issues are now treated in a more general approach. Although the changes on the learning paradigm, namely the credits for students’ work, the fact is that one cannot use the time and the approaches to consolidate or apply knowledge in the same way. Despite the care taken when adapting the courses to Bologna, employers in general looked the Bologna graduated engineers with some lack of confidence on their technical skills.

The reduction on course duration for global competitiveness puts also problems on the skills acquired and this phenomenon is not exclusive for European countries on the Bologna agreement. Rather, it tends to become a global problem. On one hand, higher education

institutions are conducting initiatives related to entrepreneurship, in order to foster creativity and innovation. But, in order to succeed, it requires technical and personal skills, which can suffer from the shortening of the courses duration. On the other hand, recent changes on laws and budgetary rules for public institutions include in its funding formula the success rate of students; the employment rate and the employment market indicators. This is even more important for public Polytechnic Institutes whose majority are small to medium size Higher Education institutions, geographically located mainly at the interior, in regions with less population, less industry and thus having fewer resources. Moreover, the acceptance and success of its graduated students are key factors for institutional reputation and course accreditation purposes, and for funding issues.

This paper is about the practice of the authors on an Electrical and Telecommunication engineering graduation course (bachelor level) at a Polytechnic School. Before the adoption of the Bologna format to courses, we supervised graduation projects in complementary and a multidisciplinary approach [1], aiming to foster team-work and the importance of accomplish task’s schedule, but also to reinforce technical skills. Since 2005, in order to overcome some lack on engineering skills and the consequences of the reduction on the duration of courses, the authors improved and reinforced the collaboration with external organizations, mainly from industry, by supervising several engineering graduation projects with direct involvement of industrial organizations. Those projects aimed to fulfill specific needs and requirements from industry, and were carried out in a non-academic environment. By this approach we intend to contribute for the success of engineering teaching and learning processes [2, 3] at higher education in general and our institution in particular.

The rest of the paper is organized as follows: section II describes the approach used and list the projects supervised. The results obtained are presented and discussed in section III and finally, the main conclusions are referred in section IV.

II. GROUP PROBLEM SOLVING

The engineer endeavour is to solve problems to the benefit of humankind. Therefore, the engineering professionals need to have the necessary skills and the ability to apply knowledge and technology to the service of the society. An engineering problem solving process, in nature, is essentially a multidisciplinary process requiring knowledge from fundamental areas, namely mathematics and physics, but also from specific or specialized core

engineering matters. Besides these, it involves also the economical perspective. Creativity, communication skills, and the ability to work as a team and critical thinking are other important characteristics to develop from engineering graduates, in order to succeed. Therefore, the reduction on skills acquired because of the shortage on the courses duration are important for engineering education. Bearing these in mind, engineering educators, and higher education institutions have to find some solutions.

The key factors to solve engineering problems are summarized into interdisciplinary knowledge and interdisciplinary processes as follows (adapted from [4]):

- *Interdisciplinary knowledge* concerning: (a) core engineering fundamentals and principles; (b) the nature of engineering problems and their multiple solutions and approaches; (c) engineering design processes in solving these problems; (d) the role of mathematical models in engineering problem solving; (e) how society influences and is influenced by engineering; and (f) ethical issues in engineering projects.
- *Interdisciplinary processes* involving: (a) engineering design processes; (b) applying mathematics and science knowledge into engineering; (c) employing creative, innovative, careful, and critical thinking in solving problems; (d) envisioning one's own abilities as an engineer; (e) trouble shooting and learning from failure; and (f) understanding the central role of materials and devices and their properties, characteristics and features in engineering solutions.

In the authors' opinion, any term year engineer graduate student must have a good and consolidated basis of knowledge that accommodates at least the majority of the skills mentioned above, although some require real practice, in order to be dully absorbed and correctly understood. It is our strong believe, in what concerns the shortening of courses and skills, that without such basis "... the options for solving complex problems, adding intellectual value to new technologies, spearheading innovation and continuing to compete globally will be severely hampered" (quoting a statement from the Australia's National Strategic Review of Mathematical Sciences Report, from Dec. 2006, <http://www.review.ms.unimelb.edu.au/FullReport2006.pdf>).

The core of engineering is the understanding of a problem, the idea for a solution, the creation, application, and evaluation of that solution, which may help to solve, predict, or explain the behavior of complex systems. A typical engineering problem solving process involves the following components:

- ASK – Know the problem, the objectives, and the constraints. What others have already done?
- IMAGINE –Brainstorm ideas on possible solutions. Discuss ideas and choose the one that best suits.
- PLAN – Draw a possible block diagram. Decompose it in tasks and establish its dependencies. Make a list of equipment and materials needed. Draw a feasible timeline diagram.
- CREATE – Design and create a prototype and evaluate it. Follow the plan and if necessary change it without loosing focus on main goals and tasks.

- IMPROVE – Discuss what works, what does not and what one can ameliorate. Improve the design and test it.

The practice adopted uses a Mind and Hands-on of Group Problem Solving approach [4-6] with focus on solving real engineering problems/projects outside the academic environment. For that purpose, prior to present the themes of graduation projects to term-year students, a contact is made with some industry or other organization responsible persons. The objective is to identify possible engineering problems that students can work with and to solve within a five-month period. At the same time, the responsible person is invited to become directly involved in the tasks, to follow-up the project inside the organization, and serve as advisor. On success, the objectives are defined, the terms of co-operation among institutions are established, a draft timeline is prepared, and if applicable, a memorandum of understanding is signed. In a superseding phase, the students form working groups (normally with two elements but can have more depending on the complexity or volume of work) choose a project theme among those offered and contact the teacher/supervisor. Upon that, a first meeting with the students, the supervising teacher, and the industry/organization advisor takes place.

The initial meeting serves for a first personal contact, so that all people involved know each other and to be aware of each ones'role within the project. It also serves to present and discuss specific needs from the industry or organization, to point out the key factors and to mention any restrictions. Normally it comprises also a guided visit to the plant or facility, which is a first contact with the equipment or application related to the project. With these two initial phases accomplished a cyclic process of engineering problem-solving starts, as illustrated in Fig. 1. Regardless the project phase, supervisor and/or advisor follow-up in a weekly basis the students' performance, their accomplishments and difficulties, although in Fig.1 just the more significant ones are highlighted.

This approach is essentially a problem based learning process. Therefore, the group of students and the objective are at the center of the all process. The students learn from what she/he does and not from what the teacher/advisor does.

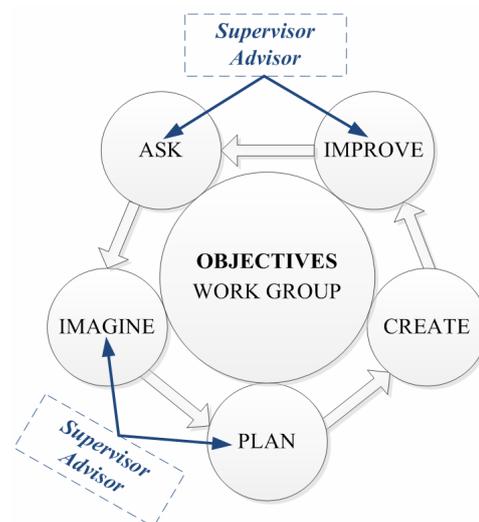


Figure 1. Cyclic engineering problem solving with advising/ tutoring.

SHORT PAPER

AN APPROACH TO FOSTER ENGINEERING SKILLS AT GRADUATION LEVEL: MEETING THE INDUSTRY NEEDS

The graduation projects occur in the second semester, usually from March to July but in some cases, due to specific constraints, some may last until September or October (special season for assessment). Therefore, in order to leave the maximum useful time for project execution, the presentation of the projects, the selection process and the preparation phase occurs by the end of the first semester.

This way, the useful time for project execution is around 20 weeks, excluding an initial and preparation phase that lasts two or three weeks. The interaction with the supervisor (teacher) and/or the advisor is made through regular meetings, which are more frequent at the initial stage of the project (2/3 meetings per week). At the initial phase students have to accomplish with several tasks, namely understand the problem and the objectives, comprehend the constraints, identify what others already made, and discuss possible solutions. This phase ends with the definition of a global execution plan and a feasible timeline. Then it moves to the subsequent phases with regular follow-up meetings on a weekly basis. At the weekly meetings, one verifies the overall execution plan in all tasks and students are asked to accomplish with the plan and define specific objectives for the next week. In addition, if corrections or alternative solutions are needed, the first objective is to engage students on finding possible solutions, to discuss the subject among the group and latter on to discuss that with the supervisor and the advisor. However, we have noticed the need for a tool to monitor the activities, the contributions, and the performance of all players involved. MEShat [7] seems to be a tool that one can use for that purpose, as it measures individual and group performance and facilitates communication in the form of blogs.

By working close to the industry, students are pushed to accomplish with tasks and on-schedule, rather than in the academic environment, which is at a certain point more tolerant. On the other hand, students gain by working on real application projects with specific requirements and constraints, which are difficult to create/simulate at the academy. In general, this approach, highly contributes to

the development of engineering skills on graduation students, on emphasizing the importance of both, time and task accomplishments, which is somehow away of a typical academic environment. Moreover, this is also a privileged way for employers to recruit young engineers, and for students to enter the employment market. Therefore, students tend to put their best efforts and commitment on the project execution, with good results on the overall performance.

The demands and stress from industry or organizations, in terms of quality, and time to accomplish with tasks pushes students' gives students the opportunity to contact with real case demands of employers. On the other hand, applied R&D projects at engineering graduation level also benefit the academic institutions in two ways: on getting some laboratory equipment as counterpart of that cooperation, and for the teaching staff development. Moreover, the overall performance of students is a good indicator on the quality and suitability of the courses. Besides, it contributes to the students' employment rate, which counts for the ranking indicators.

As part of the requirements for a passing grade and obtain the diploma, the students have to write a technical report on the project and present it for discussion for a jury in a public session. That also gives students the ability to develop technical writing and presentation skills. Depending on the quality of the solution and obtained results, students are invited to write a paper for a conference as it the case of [8-10].

Table 1 summarizes the projects supervised since the academic year 2005/2006, indicating number of students involved in each project and the associated partner entities. In round brackets, there is information on the type of organization or sector of activity.

III. INQUIRY RESULTS AND DISCUSSION

To evaluate the benefits of this approach inquiries were conducted to graduated students and to advisors from the project partner organizations. The choice for the inquiries was due to the lack of a computer-based tool to monitor

TABLE I. SUMMARY OF THE GRADUATION PROJECTS SUPERVISED

Acad. Year	#	Project Title	Students enrolled	Partner (Organiz. type)
2005/2006	1	<i>Detection of Calcifications in Digital Mammograms</i>	1	ULS (Hospital)
2006/2007	2	<i>TCP/IP Multifunctional Terminal</i>	2	PortSyst (Industry)
	3	<i>"Net-Eye" – TCP/IP based Video Surveillance System</i>	2	
2007/2008	4	<i>Digital Bio (fingerprint biometry)</i>	1	PortSyst (Industry)
	5	<i>Infrared Tag Reader for Health and Security Applications</i>	2	PortSyst (Industry)
2008/2009	6	<i>TCP/IP Multifunctional Terminal w/ biometric functionalities</i>	2	PortSyst (Industry)
	7	<i>Low Cost Data Logger for GPS Signals</i>	2	BVCB (Fire Dept.)
	8	<i>Wireless Transmission Systems for Low-Cost Data Logger</i>	1	BVCB (Fire Dept.)
	9	<i>Low-power Wireless Events Counter System</i>	2	CCCP (Public organization)
2009/2010	10	<i>TCP/IP Multifunctional Terminal w/ biometric functionalities (cont.)</i>	2	PortSyst (Industry)
	11	<i>Black-Box for Industrial Cooling Equipment with Remote Access</i>	2	Centaurus International (Industry)
2010/2011	12	<i>System for Monitoring and switch-on Backup of Power Energy</i>	2	ENAT (Industry)
2011/2012 *	13	<i>Wireless Monitoring of a Local Photovoltaic Panel</i>	2	ENAT (Industry)
	14	<i>Android Application for Remote Monitoring of Solar Energy</i>	2	ENAT (Industry)

* Unconcluded projects; still undergoing (no eligible for evaluation of the proposed approach – see Section III)

SHORT PAPER

AN APPROACH TO FOSTER ENGINEERING SKILLS AT GRADUATION LEVEL: MEETING THE INDUSTRY NEEDS

the activities and the performance of all the players from the beginning, thus treating all cases with equity.

Advisors filled their inquiry during an interview to discuss and evaluate the overall aspects of the work and the achievements. The inquiry to graduated students was conducted online, as all of them are working in the profession in different locations. The inquiries were different, according to the points of view and interests of each type of player regarding the adopted approach. Although different, they are related so that one can analyze it and correlate information.

The questionnaire for advisors comprises eight questions to score from 1 (lower grade) to 5 (higher grade) and a free writing area for feedback and suggestions. The questions presented to partners are listed below.

1. The initial role of the team work in terms of technical and critical thinking skills
2. The ability and tendency of the students for teamwork and to share and discuss ideas;
3. The complexity of the projects according to the objectives, restrictions and time to accomplish the tasks;
4. The overall performance of the working group regarding the timeline schedule and the reached objectives
5. The commitment of the working group to accomplish with tasks and objectives;
6. The overall quality and reliability of the solution;
7. The experience and the benefits for the organization;
8. The possibility of become involved again as partner in future projects.

Partners filled six inquiries and their marks for each question/item are shown in Fig. 2.

The marks given by the partners indicate a positive impression on the overall process. The results show that although students show some lack of confidence and skills at the initial phase, they were committed to success and to a positive impression on their own role. It also shows an evolution on students' performance. At the end, partners rated the co-operation experience as positive and with benefits for their organizations. They also demonstrate a

good impression and consider repeating the collaboration in similar experiences in the future. This is also demonstrated by the continuity of partnerships for several years.

All graduated students, individually, had to score a list of twelve questions with marks ranging from 1 (lower grade) to 5 (higher grade). The list of questions is as follows:

1. The importance of industry related graduation projects by the time of choosing a project theme;
2. The importance given to graduation projects in co-operation with industry or organizations when project ends;
3. The importance of co-operative work and brainstorming for engineering graduation projects
4. The importance of projects to consolidate knowledge;
5. The importance of multidisciplinary problem solving to develop technical, personal and critical thinking skills;
6. The importance of the co-operation with industry/organizations to enter the profession;
7. The complexity of the project;
8. The time to accomplish with the tasks;
9. The conditions and support provided to your group in order to accomplish with tasks and objectives;
10. The overall role of your workgroup;
11. The importance of your individual performance and contributions to the success of the group;
12. The benefits of a mind and hands-on approach in a non-academic environment for the development of your skills;

From the twenty-one eligible students, nineteen (90.4%) participated. Fig. 3 shows their marks to each item. With their answers students showed that, more than 90% give a high importance to industry related projects as indicates the marks for question 1 and 2. Approximately 84% or more fill that co-operative work, brainstorm discussions, and projects are key factors to consolidate what they have learned. Nearly 90% find problem-solving best suited for the development of personal and technical

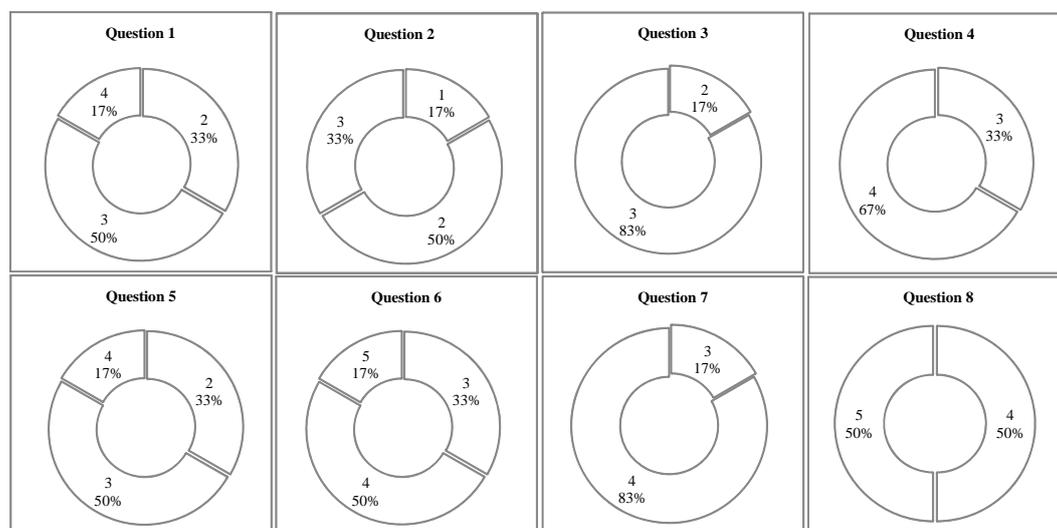


Figure 2. Overview of the marks given by partners to the questions.

skills and critical thinking. As counterpart, the majority (90% to 95%) finds a higher complexity of the proposed projects and the time to accomplish with tasks not adjusted to its complexity. That might reflect their freshmen status. Despite these, they in general considered to have good working conditions and the support provided helpful. Their individual contributions to the success of the group had also high marks, thus indicating their commitment and role to reach the objectives and the best solution. Finally, around 89% consider the proposed approach relevant for the development of their engineering skills.

Additionally the available indicators on employment success rate show that the students involved on these projects could get employed for the first time in less than three months, some of them in one month or less. The employment success rates are around 80% in the first 3 months and nearly 95% in 6 months, which are other strength points. Only two were first employed after six month from graduation.

IV. CONCLUSIONS

This paper proposes an approach to foster engineering skills by using mind and hands-on approach of performing engineering graduation projects. This is done in co-operation with industry and other external organizations to academia acting as partners. The purpose is to overcome the lack on skills due to the reduction of courses caused by the adoption of the Bologna format.

The proposed approach is supported in engineering problem solving strategies in a nonacademic environment, to foster engineering skills while meeting the industry needs. In a similar way as it happens in companies, studnets are challenged to accomplish with tasks on time,

to work as a team and pushed to reach the objectives.

The results from inquiries to both, partners and graduated students demonstrate the benefits of this approach. The overall quality of the solutions is another point to emphasize. The continuity of some partners, the growth on the number of organizations associated to the projects, and their will to keep involved highlights the benefits of the approach proposed

The indicatros of employment success rate are around 80% in the first 3 months and nearly 95% in 6 months are strength points that deserve to be mentioned.

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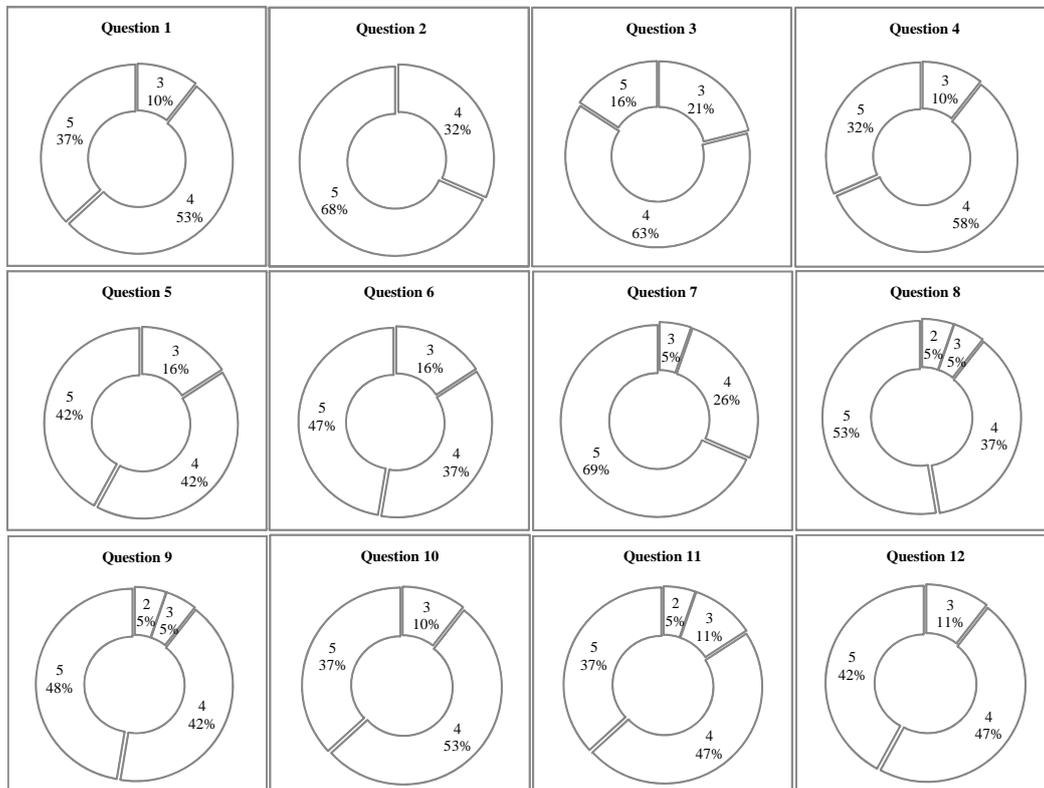


Figure 3. Marks given to the inquiry by graduated students.

SHORT PAPER

AN APPROACH TO FOSTER ENGINEERING SKILLS AT GRADUATION LEVEL: MEETING THE INDUSTRY NEEDS

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