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Evolution of Final Degree Projects at the Universidad Politécnica de Madrid*

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During recent years, it has been pointed out that the typology of Final Degree Projects (FDP) presented in engineering schools has changed. Just a few years ago, students presented predominantly classic engineering projects (installations, processing plants, etc.), whereas today they prefer theoretical-experimental works (research projects) or technical, organizational and economic studies (consulting projects). This paper shows a study analyzing the evolution of the typology of the FDP presented in the UPM ETSII (Industrial Engineers College in the UPM). As part of the research effort, more than 3,000 projects that have been presented during the last 25 years have been analyzed. This analysis has confirmed the preferences of the UPM engineering students for FDP. The results of this analysis will facilitate the identification of the competencies and skills that the students need to develop.

Keywords: final degree project; typology of projects

1. INTRODUCTION

THE OFFICIAL SPANISH DEGREE of Industrial Engineer allows the bearer to directly enter doctoral programs at any Spanish university. The degree is given by a university (a public, state-owned university) on behalf of the King of Spain and is therefore not only accredited, but also official. It also allows the bearer to become automatically a full member of the Official College (professional association) in Spain and, thereby, a registered engineer and to work as an engineer anywhere in the country.

A student enters university at the age of 18 (after 12 years of formal education). There is a minimum high school grade required to join a school within the University. ETSII (Escuela Técnica Superior de Ingenieros Industriales de Madrid) is very selective, and requires one of the highest Grade Point Average (GPA) entrance levels of all the Spanish university centers.

Graduation in ETSII requires five full-time years plus an engineering thesis or FDP, which is necessary to become a registered engineer [1].

The Final Degree Project (FDP) is an activity that is undertaken at the end of the engineering course, and passing it is required in order to obtain a degree in engineering [2]. At the ETSII, the FDP is regarded as an individual task to be performed by a student, who, under the guidance of one or more tutors, designs a solution that is capable of properly satisfying a real need and is of such a level of complexity that it requires the application of the knowledge and training acquired throughout the length of the student's studies [3, 4]. It must be an individual task. No teamwork is allowed. Several group assignments during the grade are required and competencies and team work, leadership, and negotiating skills are developed. In this case, other important skills are expected. Projects are multidisciplinary and so it will be necessary for students to work together, applying the knowledge and training that they acquired during their studies in different disciplines. In addition, the student must apply this knowledge to satisfy a real need [5, 6].

In the past, those projects used to be classic engineering projects, according to the definition that we will see. However, during the last twenty-five years, there has been an important change. The results of our evaluation of this change are presented here.

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2. LITERATURE REVIEW

2.1 *Project-based learning*

There is a shift in emphasis in engineering education from professional skills to process skills [7]. These skills include problem analysis and problem solving, project management and leadership, analytical skills and critical thinking, dissemination and communication, interdisciplinary competencies, intercultural communication, innovation and creativity, and social abilities. Project Based Learning (PBL) has proved to be an excellent method for development of new forms of competencies [8, 9].

Research has shown that students retain minimal information in the traditional didactic teaching environment and frequently experience difficulty in transferring the acquired knowledge to new experiences [10]. A PBL environment enables students to draw upon their prior knowledge and skills, brings a real-world context to the classroom, and reinforces the knowledge acquired by both independent and cooperative group work [11].

PBL is a model in which learning opportunities are organized around projects [12, 13]. According to the definitions found in PBL papers, projects are complex tasks that are based on challenging questions or problems that involve students in design, problem-solving, decision-making, or investigative activities. They give students an opportunity to work relatively autonomously over extended periods of time and end in realistic products or presentations [14, 15,16]. Other defining features of projects that have been found in the literature include authentic content, authentic assessment, and teacher facilitation without direction, explicit educational goals [17], cooperative learning, reflection, and incorporation of professional skills [18].

2.2 FDP at ETSII UPM

The FDP is an activity that is carried out at the end of the engineering course, although it can begin before passing all courses. Passing it is a requirement for obtaining a degree in engineering. The FDP's scope and assessment are subject to the Academic Regulations of Madrid Polytechnic University and are specified for the ETSII in the FDP Regulations that have been approved by the School Board (July 2007) and by the Vice-Chancellor of the UPM [1].

FDP's objective is to help students acquire a combination of theoretical-practical knowledge that is additional to what they have learned in their degree subjects and also to acquire a series of personal skills that will enable them to demonstrate that they are ready to be successfully integrated into the labor market at the professional level accredited by their degree [19]. Therefore, the FDP work must be similar to what students will do when starting out on their professional careers after completion of their studies. The skills that students are expected to acquire are:

- to be able to apply their knowledge of sciences and basic technologies to the practice of Industrial Engineering;
- to be able to design, develop, manage, and improve products, systems and processes in the different industrial areas, using analytical technologies (skills), computing or experimental properly;
- to be able to apply the acquired knowledge to identify, formulate, and solve problems within ample and multidisciplinary contexts, being able to integrate knowledge;
- to understand the importance of working in professional and responsible surroundings; and to be able to include the impact of industrial engineering in the sustainable development of society;
- to be able to communicate the knowledge and conclusions, in oral and written form, to both the general public and specialized publics clearly and without ambiguities.

However, it must not be forgotten that the FDP is a task to be performed within an academic framework, and it is there that it must be presented and pass.

Therefore, the FDP must satisfy both an academic requirement and a professional requirement. To satisfy the academic requirement, it is necessary to use much of the knowledge acquired throughout the degree in a coordinated manner. To satisfy the professional requirement [20, 21], one must attempt to solve a set of interrelated and complex problems by choosing an alternative that is realistic in technical aspects, timeframe, and expense. Both requirements have important implications [22].

What is currently understood by project is "the combination of all the resources that are necessary, brought together in a temporary organization, to transform an idea into reality" [23]. When this definition is applied to the FDP, there are certain aspects that require consideration. First, FDP is often unable to encompass all of the stages of a project, particularly if it must be brought into physical form. In this case, it is acceptable to limit it strictly to the documentary stages that will deal with the project as a whole, provided these stages are of sufficient breadth. Although this is a possible option, no opportunity should be missed to carry out the complete process (e.g. building an experimental prototype).

The interest in endowing the FDP with a real, practical sense has meant promoting good relations with a large number of companies. The result is that many of the current tasks correspond to actual projects—or are part of a wide-ranging project that students develop as scholarship students in very varied companies. This practice is producing excellent results. Apart from gaining experience in designing, organizing, and controlling a project that is assigned by the tutor, students are also provided with specific technical support by the persons who supervise their efforts inside the company.

2.3 European Higher Education Area

Having defined the FDP and understanding its importance in the training process, it should be considered to be the final step in the study plans and, consequently, in the training process. Each country and even each university approaches the FDP with a different number of credits required, minimum and maximum duration, location and method of carrying it out, its typology, etc. In this sense, Europe has been working for many years to improve its university education system and make it more homogeneous [24–28]. This began mainly in 1988 when some vice-chancellors from European universities signed the Universities

Magna Carta. Then, in 1998, the so-called Sorbonne Declaration appeared in which four European ministers of education participated and finally in 1999, the so-called European Higher Education Area (EHEA), but better known as the Bologna Declaration, was signed in the city of Bologna (Italy) by 29 European ministers of education. Universities in Spain have until 2010 to adapt to this treaty. It seeks to ensure that university degrees have the same value from one country to another (within the EU and certain other countries), and facilitate the movement of students and teachers, and provide incentives for research and development (R&D), as well as cooperation between European countries, to ensure a high level of quality education, etc.

The analysis presented in this paper and its reflections on the evolution of the typology of FDP will also contribute to identifying the most important student competences and skills to adapt the education system to the Bologna Declaration. A study of final projects was conducted at ETSII-UPM. However, its results have not been compared to those of other Spanish universities because there is no published information on this subject.

3. RESEARCH PROJECT

The typology and nature of the FDP in the Industrial Engineering Degree is as rich and varied as the industrial sector for which the student taking the degree is destined [29]. Despite this, and without wishing to set boundaries, in order to carry out this study, the following three categories have been considered:

- *Category 1: Classic engineering project.* The main feature of this type of project is that its framework must be adapted to the requirements of official projects that need a stamp from the Official Collegiate Bodies (i.e. must include a report, plans, specifications and a budget). Most projects of this type involve industrial facilities or the implementation of a procedure in an industrial sphere. However, machine design or any system to be delivered to a customer under certain conditions [30,31] is suitable for a FDP.
- *Category 2: Theoretical-experimental work* that makes a contribution to technology in various fields of engineering, including, financial assessment and discussion and assessment of results. Many FDPs that are developed in the university laboratories belong to this category. These would include all kinds of R&D finite element calculation of mechanical systems, computer applications development, computer simulations of physical-chemical principles, etc. [32–36].
- *Category 3: Technical, organizational and economic studies* related to equipment, systems, services, etc. that are linked to the scope of the degree and deal with any aspects of design, planning, production, management, operation or any other engineering field-related issue, and list, when appropriate, various technical alternatives with economic assessments and the ensuing discussion, and results assessment. Fitting into this category, for example, would be strategic marketing plans, quality plans, a feasibility studies or technical reports on an industry sector(s) [37, 38].

The increasing number of FDPs that have been developed with the support of industry contributes to their diversification and also to their contribution, however modest, to the growth of industry's technological assets.

3.1 Research methodology

The analysis of FDP from 1984 to 2008 has been conducted by students at the ETSII-UPM. It was necessary to obtain the assistance of the computer science department as the FDPs were not available in digital format before 1995. In order to obtain a statistically significant sample size, more than three thousand projects dating back to 1984, were analyzed.

For this analysis a data base of the FDP presented during those years has been created. Nine specializations were studied in the analysis. They are electronics, electricity, construction, mechanics, materials science, industrial management, chemistry, energy technologies, and manufacturing.

We will call Typology to the categories in which an FDP can be classified:

1) classic engineering projects;
2) theoretical experimental work;
3) technical, organizational and economic studies.

There are two databases available. The first contains data belonging to 12 years, the three oldest being 1985, 1986 and 1987. The 1994 year serves as a midpoint. For these four years, the only information that is available is the typology of the FDP, the student's gender, and the student's graduation year. The final years correspond to those years for which a new study plan for the Industrial Engineering Degree had already been implemented. For five transitional years, we have the FDP for both plans and also the nine specializations studied.

4. RESULTS

A descriptive statistics tool, the bar chart, is used for the analysis. It is a chart that contains rectangular bars that have lengths that are proportional to the values that they represent. Are usually used for comparing two or more values. A statistical treatment was performed with the help of the computer tool, Statgraphics. First, a comparison was made between the typologies of the FDP, which is already stated in the foregoing section.

Figure 1 shows the number of FDP for each

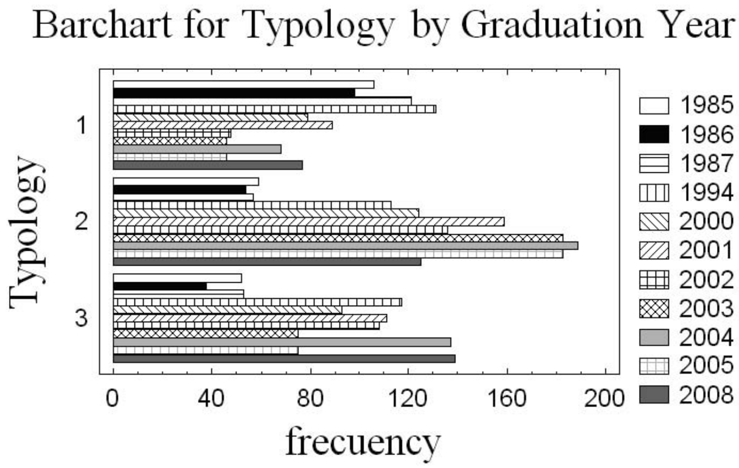

Fig. 1. Typology vs. graduation year.

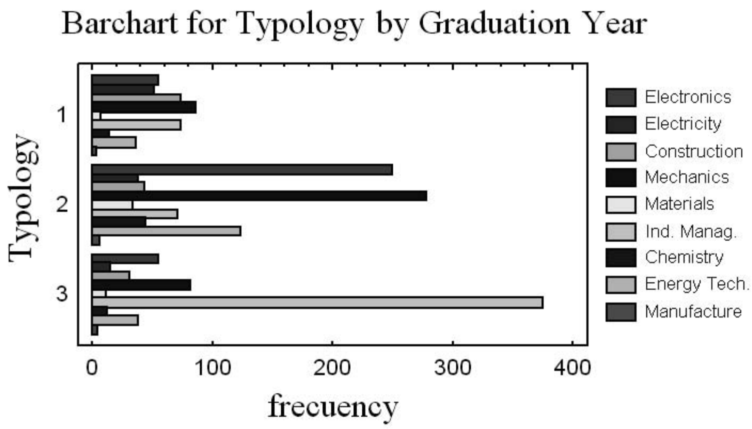

Fig. 2. Typology vs. specialization.

typology that have been carried out for each year. The figure shows that in the earliest years, and even in those that can be considered as intermediate, most FDP fall into category 1 (classic engineering projects), whereas in later years these are done as part of the other categories (innovation and organizational projects). If, in addition, we examine the specialization by typology, we obtain the results shown in Fig. 2.

It is worth pointing out how the FDP in specialities represented by electronics, mechanics, and energy technology fall into the typology of research and development, whereas speciality industrial management clearly falls under organizational studies. The speciality in which most FDPs are classic engineering projects (typology 1) is speciality construction.

5. DISCUSSION

In PBL, the project is the central teaching strategy. Students encounter and learn the central concepts of the discipline by means of the project. There is a longstanding tradition in schools of "doing projects," incorporating "hands-on" activities, developing interdisciplinary themes, conducting field trips, and implementing laboratory investigations [39].

Research on PBL can be undertaken to:

1) form judgments about its effectiveness (collective evaluations);
2) assess or describe the degree of success resulting from implementation or performance of Project-Based Learning (formative evaluation);
3) assess the role of student characteristics in PBL effectiveness or appropriateness (aptitude-treatment interactions); or
4) test a proposed feature or modification of Project-Based Learning (intervention research) [40].

Moreover, there are at least three traditions from which PBL research and practice seem to emerge. They are:

1) Outward Bound wilderness expeditions [41, 42];
2) postsecondary models of PBL [43, 44];
3) university-based research in cognition and cognitive science applications [45–47].

The inclusion of real-world problems in engineering education reinforces concepts and improves learning in ways that are not available by traditional lecture methods or predefined case problems [48]. Students develop problem solving skills, project management skills, communication and teamwork skills, and a sense of professionalism from such experiences.

FDP provides a student with an opportunity to prepare for a professional life by practical training in coordinating a work group and working effectively as a member of a team. The independent research and learning aspects of the PBL provide the students with the skills necessary to identify the information that is missing for the types of problems that they may encounter during their professional lives, conduct the necessary research, and discover the missing information.

The purpose of this practice was not only to enable students to acquire technical knowledge, but also to open their minds and see what engineering project management is really all about.

This experience has demonstrated that project-based learning is an effective way to effect student learning in the subject area of project management. In addition to detailed technical knowledge and performance skills, successful project management requires engagement, motivation, creativity, and understanding.

In this research, it has been shown how the preferences of students to select FDP has evolved over time from the classic engineering project with an emphasis on documentary aspects to a much wider and more varied view of what a project is with the appearance of a large number of projects linked to research or organization—which was unthinkable several years ago. The preference for choosing particular typologies, depending on the student's speciality, has also been shown. Students who choose the Industrial Management speciality prefer to work in organizational studies, whereas those who choose the Construction speciality continue to prefer classic engineering types of projects. The students of other specialities, such as electronics, energy technologies or mechanics, usually choose research and development projects.

6. CONCLUSIONS

The analysis presented here has enabled us to discover which FDP are preferred by students in engineering schools, particularly in UPM. The results clearly show that the preferences of these students have shifted from classic engineering projects to other areas related to technical, organizational, and economic studies. By the time the student undertakes an FDP, the last stage of the degree has already been reached and subjects that foster teamwork, leadership, and negotiation skills have been passed. However, it is expected that the student will acquire additional skills and competencies as a result of the FDP-related work, such as those presented in this paper.

Once the results of the study are examined, we will be able to question whether the competencies and skills developed by the student vary by the type of the project implemented. This research is currently being executed by the team presenting this paper.

Finally, it is important to be aware of the significance that FDP will have for the future implementation of the new engineering degrees. The new educational system gives the FDP greater recognition than the present system. In turn, the FDP will provide a great opportunity to develop necessary competencies.

It is probable that the evolutionary trend in the typology of FDP will become part of the new degrees, with some typologies standing out in some degrees to replace present-day specialities.

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