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Relationship between Specific Professional Competences and Learning Activities of the Building and Construction Engineering Degree Final Project*

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This paper presents a study in the framework of Building and Construction Engineering Degree. The aim of our proposal is to discuss if the academic activities comprising the Final Degree Project (FDP) are corrected, balanced and adapted in order to maximize the acquisition of the competences identified by the professional sector through two rounds of quantitative surveys (data also presented in this paper). Due to the economic and construction crises and the decreasing number of students in this sector, it is essential to ensure that future professionals are trained in a specific way to meet the current needs of the sector. Based on our assumption, the data obtained in the surveys, and the analytic approach of the main academic indicators, we propose new relations and FDP evaluation methods that would align the student's curriculum with the current professional needs. The obtained results reveal the need of changes in the current FDP structure in order to give more importance to certain learning activities identified as essential at the professional level. With our proposal, we will improve the FDP evaluation, and the student competences acquisition, in order to adapt them to the professional needs.

Keywords: building engineering studies; academic and professional competences; learning indicators; educational assessment; academic analytics

1. Introduction

This article is based on an investigation aimed at identifying the fundamental variables that should comprise the Final Degree Project (FDP) of the Building and Construction Engineering degree in order to improve students' professional competences. The motivation of this study is based on the current situation of the Engineering and Construction sector in Spain. Because of the economic crisis started in 2007–2008, there has been downsizing in the labor market within this sector, which adds to the drastic drop in number of undergraduate students in the sector of architecture and construction engineering. Due to these factors, it is necessary to make adjustments in the academic plans in order to adapt them to the needs of the labor market, thus optimizing their incorporation in a changing and highly technical training.

The Building and Construction Engineering degree is exclusive to Spain and has been restructured since the implementation of the Bologna plan [1], which involved several changes in its name, along with adaptations of each department and the course component in order to align the academic plans with the Bologna principles [2]. As it happens at the level of global degrees, the majority of subjects focus on imparting closed concepts. The content modifications always have a certain administrative complexity (lack of time, budget) and technical (reluctance of the faculty members to modify the content of the subjects). But something that differentiates this degree is that it enables students to have a profession with very specific attributions within the framework of construction engineering. For this reason, it is necessary that the FDP is located at the end of the studies and it should be updated, as it integrates the skills assessment that a professional must have in this sector. The FDP needs to be adapted to the constructive needs of today's society, and therefore, it is necessary to guide and evaluate how processes of change and update can be carried out.

The first main objective of this paper is to identify the principal competences demanded by the professional sector and formally relate them to the learning objectives defined for the FDP assessment. These relationships establish a new method for identifying, incorporating and analyzing both learning and academic objectives in order to improve the way that students acquire skills and competences during their Building and Construction Engineering undergraduate studies in Spain. Every institution that offers this degree employs staff exhibiting substantial differences in the abilities and competences, which are also reflected in the

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adopted systems and curricula. These differences are due to the numerous interpretations of professional and/or territorial requirements, an approach that will be presented in this paper based on extant data [3] and discussed using new data from a new study developed in the context of the current project.

The second main objective is to continue an analytic work started in [4], that is located in the first stage within the three main levels of academic analytics, that can be described as: identification and categorization of learning indicators, explanation of learning and teaching behaviors; and adaptive correction of the learning processes.

Section 2 (Presentation) of this paper includes an overview of the academic and professional context of the Building and Construction Engineering studies in Spain, along with the characteristics of learning and academic analytics approaches used to analyze the educational data that affects the FDP student development. As detailed discussions of this data can be found elsewhere [4], for brevity, we will focus only on the basic information obtained from [3] in order to establish a preliminary link between variables. The data yielded by a new survey was used in order to validate the previous findings, as well as identify changes that need to be made in the FDP structure and assessment methods. As explained in Section 3 (Discussion), the aim is to improve the students' academic level and prepare them for the professional career. Section 4 provides the final discussion of the study findings, while the main conclusions of the research are presented in Section 5.

2. Presentation

2.1 Academic and professional framework of building and construction engineering degree in Spain

At present, the Building and Construction Engineering profession in Spain is regulated by the current legislation, and each professional requires a current degree title in order to work (as provided in art. 12.9 of the RD 1393/07 according to the established conditions in the minister council proposal of 14.12.2007). The requirements of the study plans that should be followed by institutions offering a technical architect degree must meet the ECI/3855/2007 order issued on December 27th [5].

The first references to the Quantity Surveyor profession (known as "Aparejador" in Spain) can be traced to the construction of the Monastery of San Lorenzo del Escorial in 1562 [6], which was at the time performed by the construction manager. It was not until the publishing of the Royal Order of January 24th, 1855 and the Lujan decree that the profession was officially denoted as *Aparejador* [7]. Such nomenclature persisted until 1971 (Royal Decree 265/1971) [8], when the Building and Construction Engineering competences were established and regulated [9]. According to these regulations, the *Aparejador* should possess knowledge, skills and aptitudes that would allow him/her "To inspect with proper assiduity the material execution of the construction process, being his responsibility for it to develop according to the project and the right construction practices" [10].

However, owing to the rapid technological changes and the increasing demand for more complex and innovative structures, the role of the Aparejador has become much more diverse and carries a much greater responsibility. In line with the ECI Learning Goals (LG#) [5], our FDP presently comprises of the following components:

- Learning Goal 1 (LG1): Directing the material execution of building construction projects, their facilities and elements, along with carrying out the quantitative and qualitative control of the construction. This goal also pertains to the management of control plans of materials and systems and execution of the work, as well as drawing up the corresponding records for inclusion in the technical book of the building. The work related to this goal culminates in taking control of the work by performing the certifications and the liquidation of the project.
- Learning Goal 2 (LG2): For this goal, the student must prepare studies, security plans, and occupational health and safety plans. In addition, he/she is responsible for coordinating the activities of the companies in charge of behavioral safety in construction places, both in the design and the implementation phase.
- Learning Goal 3 (LG3): This goal requires the student to carry out technical activities of calculation, measurements, valuations, appraisals and economic feasibility studies. The student is also responsible for conducting surveys, inspections, and analysis of pathologies and other problems of similar nature, and must draft all relevant reports, opinions and technical documents. As a part of this goal attainment, the student must also design the layouts of plot and buildings.
- Learning Goal 4 (LG4): This goal focuses on developing technical projects and exercising the direction of building construction projects in the field of legal empowerment.
- Learning Goal 5 (LG5): To attain this goal, students are required to manage the new building technologies and participate in the quality management initiatives. They must also carry out

analyses, assessments and certifications for energy consumption, as well as sustainability studies.
- Learning Goal 6 (LG6): As a part of this goal, students must demonstrate strong capacity to manage the use, conservation and maintenance of the buildings, and are also responsible for drafting the basic technical documents. Studies of the lifecycle of materials, construction systems, and buildings are also part of this goal attainment process, as is demonstrable ability to manage the treatment of waste in the construction and demolition of buildings.
- Learning Goal 7 (LG7): This goal is attained when the student can provide technical advice in relation to the processes employed in the manufacture of elements and materials used in the construction of buildings.
- Learning Goal 8 (LG8): Finally, as a part of this goal, students must demonstrate ability to manage the real estate process as a whole. In addition, they should be able to provide technical representations of the construction companies in building construction works.

These LG will be later related with the variables identified in the study in order to propose improvements to the current FDP assessment method.

2.2 Assessing training: academic analytics

As we have previously explained, the research focuses on identifying and quantifying the academic variables that affect the development of the FDP, along with the learning activities currently defined in the FDP, and the professional competences that are most demanded by the sector. Once the identification and quantification process has been completed, a new relationship and proposal will be established to improve the current FDP in order to adapt it to the current market needs. While the data of the competences will be extracted by studying the data obtained from the surveys presented in section 3.3, the study that the learning activities and academic variables have or should have in the development of the FDP, is a work that we can circumscribe in the field of evaluation and analysis of the teaching activities.

While no specific definitions are provided in the academic context, training assessment can be understood as "the process of evaluating and analyzing organization data received from university systems for reporting and decision making reasons" [11]. In line with this definition, Learning Analytics has emerged as a means of assessing knowledge attainment in relation to specific learning objectives. In most cases, it is based on the evaluation of learning outcomes achieved at the end of training (based on the effectiveness of training, where objectives, content and design of training become the object of evaluation). Ferguson defined Learning Analytics as "the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs" [12, 13].

In addition to Learning Analytics, Academic Analytics are employed to analyze the training process in all the educational stages, including those preceding the training initiatives and their outcomes. As a part of this process, the variables that might have influenced the effectiveness of training activities are identified and their contribution to the outcomes evaluated [14]. Academic Analytics is a mixture process for providing higher education institutions with the data necessary to support operational and financial decision-making [15]. We can assume that under the Educational Data Mining [16], exists the global idea that supports both Learning and Academic Analytics. While Learning Analytics are focused on the course-level and departmental data (in order to improve the students and the faculty), Academic Analytics are more focused on other indicators [13], clearly related to main topics of our research:

- Learner profiles, performance of academics, and knowledge flow: As we will later develop, one of the first aspects studied [4] has been the compilation of data based on the students profile, their academic performance and the workflow associated with the activities of the FDP. In the present work, the previous data will be analyzed in order to delimit the optimal typology of FDP and its better follow-up.
- Comparisons between different learning systems (institutional, regional or national/international levels): Clearly, this aspect is integrated into our research. Thanks to the replication of the survey and the comparison of results presented in this article (see section 3.3), the results of the key competences to be developed in the FDP are compared at regional and institutional level.

In both research and practice, Learning/Academic Analytics have demonstrated their utility in identifying variables that influence learning outcomes and establish relationships between specific competences and educational methodologies and curriculum structures [17]. It is adopted when evaluating education and/or training programs, because it can identify the system's strengths and weaknesses. Moreover, regular assessments allow monitoring resource use, while also empowering the stakeholders. Similarly, assessments should be performed when the need for a change has been

identified, as this allows identification of the most pertinent issues. Regular assessments should be conducted following a system change in order to ensure that it has indeed occurred and measure its effects in both the institutional and social context [18].

The Building and Construction Engineering studies have suffered a serious crisis of students in the last decade (2007–2017), being able to classify the causes due to changes within the European Higher Education Area (EHEA, with a changes in the duration and name of the degree), the changes of the Technical Code of Edification (TCE [19]), and other social/economic factors, as the construction sector crisis. For all these reasons, it is necessary to study and establish new relationships between the academic indicators, which Academic Analytics framework defines, and that are related with the FDP, the last activity before the start of their professional life.

3. Case study

In the following sub-sections, we will focus on the input variables of our study. Our discussion commences with the key features of the FDP presently adopted in the Superior Technical School of Architecture of La Salle (*Escuela Técnica Superior de Arquitectura La Salle*, henceforth referred to as ETSALS). Next, we will relate each of the previously outlined learning goals with specific activities, exercises and learning objectives with the aim of weighting on the basis of monitoring and correcting. We presented our initial results at the International Conference Technological Ecosystems for Enhancing Multiculturalism (TEEM 16, [4]), where specific student variables were related to the process of developing the FDP, as well as to the final mark and their future preparation. In the last two sub-sections, we present the results yielded by analyzing the responses to the external professional survey, as well as those conducted at the domestic level. The information obtained through this process allows us to categorize the professional skills demanded by the sector, as well as establish their relationship with the LGs currently set out in the FDP of ETSALS.

3.1 Characteristics of the FDP at ETSALS

Since the year 2000, when the FDP was first incorporated into our engineering studies curriculum, several changes have been made. Nevertheless, equipping the students with skills and knowledge needed to solve technical and economic problems they would encounter in their professional sector remained our ultimate goal. Thus, to test the students' readiness to adopt a professional role, as a part of the FDP, they are required to demonstrate the knowledge gained as a part of the course through an execution of a practical project, in line with the current standards and practices of the profession. By the time students are given the project, they should be ready to utilize the information obtained during the degree and transform it into final decisions. The project's development methodology is structured in accordance with the initial problem that needs to be solved. This project is developed concerning the technical, legal and economic aspects, usually leading to a complete executive project.

The FDP encompasses different learning goals (LGs), which are aligned with the professional tasks performed as a part of a real project, such as security and quality controls, pacification and realization of a maintenance plan [19]. For their evaluation, we have designed different activities/content/learning exercises linked to each LG. These exercises or tasks relate to specific project objectives. According to the current regulations, the FDP aims to accomplish the following learning goals:

- LG1: Ability to conduct quality control exercises, economic certifications, measurement and control of the total project cost, according to which the work should be scheduled and planned.
- LG2: Competence in conducting health and safety controls.
- LG3: Calculation of facilities and structures, lifting of the current state of the work and study of injuries, topographic and geotechnical study.
- LG4: Development of executive projects and specifications.
- LG5: Energetic efficiency studies, along with research into new technologies and planning of the FDP.
- LG6: Use and maintenance of plans, as well as study of the environmental criteria and waste management.
- LG7: Elaboration of construction details and case studies of constructive systems.
- LG8: Ability to perform historical background and feasibility studies, as well as manage grants and subsidies, and perform audits of prior documentation.
- For the evaluation of the FDP in terms of these specific objectives, as well as for grading the final presentation, the template shown in Fig. 1 is used.

The methodological approach adopted in the present study is based on the official records of the Grade approved by ANECA (Agencia Nacional de Evaluación de la Calidad y Acreditación). The different criteria used by the evaluators are provided in a mark-table, which is subjected to lineal parameterization in order to obtain the final FDP grade

BUILDING ENGINEERING DEGREE
Assignment of Learning Goals of FDP

STUDENT: YEAR

PROJECT TITLE:

Learning Goal(ECI_3855_2007)	CONTENTS	MARK	30%	30%	40%	
1	Quality control exercices	5,5	5,8	5,0	6	
	Measurament	6				
	Economic certifications	5				
	Total cost	6				
	Working planning	6,5				
2	Health and safety exercises	3	3,0	5,0	6	
3	Facilities	6	5,7	6,0	6	
	Structures calculation	4				
	Injuries studies	5				
	Lifting of the current state	5				
	Topographic	7				
	Geothecnical study	7				
4	Executive project	5	5,5	5,0	6	
	Specifications	6				
5	Energetic efficiency studies	6	5,0	5,0	6	
	Research in new tecnologies	5				
	Personal planning	4				
6	Use plan	5	5,8	5,0	6	
	Environmental criteria	6,5				
	Waste managment	6				
7	Construction details	5	6,8	5,0	6	
	Case studies of constructive systems	8,5				
8	Feasibility studies	6	5,0	5,0	6	
	Manage grants and subsidies	4				
	Audit	4				
	Historical background	6				MARK
FINAL MARK			5,6	5,2	6	6

Fig. 1. Example of the template used for the FDP evaluation.

for each student. The current system utilized in the FDP evaluation is based on [20]:

- FDP-A: 30% of the overall mark: Project's rigor and the quality of the documentation presented by the student. (LG 1–8)
- FDP-B: 30%: The corrections made on the work. (LG 1–8)
- FDP-C: 40%: The project defense in front of the university panel. (LG 1–8)

In each of these categories, the student's contribution can be rated as excellent, good, fair or failed. An example of headings corresponding to the assessments pertaining to the first group (FDP-A) is shown in Fig. 2, where the shaded box indicates that it is obligatory to reach the pass level.

On the other hand, a significant portion of the final grade is based on the record of the mandatory monthly corrections (10 at the minimum, although their number usually exceeds 20). This activity is assessed under FDP-B, which comprises of a series of sections pertaining to specific activities. As a part of the mandatory corrections, the advisors not only provide valuable feedback on the student's work, but also evaluate the degree to which their prior comments and suggestions had been incorporated, especially the recommendations pertaining to the technical quality of the work and the methodology used. During the corrections that are performed in class, the team of teachers focuses on the following aspects:

- The personal planning of the work.
- The application of the knowledge obtained during the course.

TFG-LG [1-8]	Excellent	Good	Fair	Fall
	El FDP developed by the student has:			
Quality of the documentation submitted by the students: (3 points)	All the items, with a good structure, redaction and tools for a correct management of the project (3 points)	All the items, but with some lack in one or more of them (2'25 points)	All the items, but with some lack or significative errors in one or more of them (1'5 points)	Great lack and errors in one or more of them (0'5 points)

Fig. 2. Example of FDP-A heading.

- The ability of the student to conduct research and incorporate the findings into the project work.
- The student's capacity for synthesis and the level of objectivity.
- The student's attitude toward the work and challenges encountered in the process of project development.

In a previous phase [4], we have analyzed two periods: 2004–2007 (PRE Bologna stage), and 2012–2015 (POST Bologna stage). They were chosen as they reflect the systems in place before and after the implementation of the European Superior Space Training. From the point of view of the project, the synthesized data that characterizes the type and the Final Mark obtained (FM) is summarized in Table 1.

Although we were unable to clarify some data pertaining to the PRE phase, the typology of FDP in both stages seems fairly balanced and is largely similar. To estimate the probability that results are significantly similar, we used the Student's t-test, and tested a null hypothesis (H_o) that there are no differences in scores between variables. While, in the initial period, no significant differences between the grades according to the type of project were noted, in the POST period, we found a statically significant difference between projects focusing on a new construction and those pertaining to rehabilitation. As P(T) = p two-tailed is 0.02, which is less than the threshold of 0.05, this means that there is a very high probability that the results are different.

Table 1. Typology of FDP and the Final Mark Average

	Pre # 32 (2005–07)		Post # 24 (2013–15)	
Theme	**%**	**FM**	**%**	**FM**
New building	31.2	6.4	45	7.2
Rehabilitation	50.0	6.6	50	8.4
Without data	18.7	7.0	5	8.0
With basic project	25.0	–	45	–

We also analyzed the data pertaining to the project type, and our findings are presented in Table 2 in the form of the final mark obtained by the student (FM, Final Mark), the number of corrections that were made (CN, Correction Number) and the period (S, Semester) in which the work was developed:

Comparing the results obtained in the two periods, an increase in the final FDP mark is evident. More specifically, while the overall mark in the PRE period was 6.67, it increased to 7.86 in the POST period, which is a statistically significant difference (p = 0.0006). These findings pertain to all project types and all individuals. We postulate that two factors influenced these discrepancies: the student profile or the new methodology used for the tracking the FDP. The greatest novelty of the new methodology stems from the new typology of corrections and the technical code tracking (at least in the first year), as can be seen in Table 2.

As recognized, the number of corrections that the student has done during the work is the key measure of the work performed during the FDP development. Consequently, we have analyzed the relationship between the final FDP mark and the number of corrections that were made in each semester, and the results are shown in Table 3.

The data shown in Table 3 indicates that a higher number of corrections does not correspond to a better final mark, but rather suggests student's lack of knowledge or perceived project difficulty. In this specific case, 16 to 17 corrections were required per semester by a "regular" student. Thus, we posit that this pace of work yields better FDP outcome.

Table 2. Final Grade, number of corrections, and number of subjects as a function of the FDP typology

	Pre			Post		
FDP Theme	**FM**	**CN**	**S**	**FM**	**CN**	**S**
New building	6.40	14.50	3.4	7.18	22.27	4.0
Rehabilitation	6.62	12.25	3.2	8.41	18.75	2.6
Without data	7.00	11.66	3.6	8.00	25.00	3.0
Total	**6.67**	**12.63**	**3.4**	**7.86**	**22.00**	**3.2**

Table 3. Final mark as a function of the number of corrections (CN)

Number of corrections based on the FDP semesters	Final Mark				
	6	7	8	9	10
2–Sem (CN)	17.5	18.0	15	16	17.5
4–Sem (CN)	24.0	20.6	30.5	–	–
6–Sem (CN)	–	–	24.0	31.0	–
8–Sem (CN)	53.0	–	–	–	–

The project assessment culminates with the oral defense (the assessment group identified as FDP-C), as a part of which the student presents the work on the project and its key outcomes.

3.2 Analytic approach of student profile and FDP variables

This project is grounded in the findings yielded on a previous phase, where we started identifying the specific factors (both academic and those of personal nature) that can affect the FDP development and the final grade obtained. As a part of that investigation, we have identified and compared different indicators belonging to two academic periods based on the final projects presented to the board of examiners. Throughout the training process, links between the identified variables and the blocks defined by ANECA [21] were made, focusing on:

- The typology and theme on which the project will be based: New construction or rehabilitation, and research and technology.
- Time invested into project development (if spanning two or more semesters).
- Aspects or variables directly related to the personal situation of the student: if the student was employed while developing the project, and the number of other subjects studied alongside the project development.
- Issues related to the logistics of the classes: e.g., the number of corrections requested throughout the development of the project.
- The variables directly related to the student's academic performance: The student's academic performance in general, and the mark received for the FDP in particular.

From the results obtained [4], it is evident that both the construction and the education sector had been affected by the recent economic downturn, which has resulted in a renewed motivation for the search of excellence in an increasingly competitive society. Comparing the results obtained in the two periods studied (2004–2007 vs. 2012–2015), it is evident that the final FDP mark increased from 6.67 to 7.86, which is a statistically significant difference (p = 0.0006), as we have seeing in the previous section.

Considering all the results reported in our previous study, the higher success rate (as indicated by the final mark), is obtained for FDPs in the field of rehabilitation, when it was completed in two semesters. Taking into account these results, and following the future lines described in [4], multiple regression analyses were conducted. Using this approach, we can study the relationship between two independent variables (the average grade obtained in the course and the number of corrections required for the FDP completion), and the FDP final mark as the dependent variable. The main aim of this study is to identify the correlation between the main variables observed that affect the FDP mark. We have selected 24 FDPs submitted in the second period (2013–2015), as described in [4]. This resulted in the following model:

FDP (Y, Final Mark) = –5.808 + 2.315 (Degree average) – 0.019 (Number of FDP corrections)

Analyzing the model obtained and based on the null hypothesis (H_o) that the FDP is not influenced by the independent variables, the result of the F critical value (p = 0.002) indicates that the variables are significantly interrelated, as confirmed by a residue of 0.982, which is below the critical level of three [22, 23]. On the other hand, the coefficient of determination (R^2), which measures the goodness of model fit, at 0.5003, is at the lower limit indicating acceptable fit to the data [23].

The model obtained indicates that only 50% of the grade received for the FDP is explained by the independent variables. The result suggests significant influence of the grade by other variables not studied in our project, and that can be identified in future works.

Using the current system of FDP evaluation, based on the ponderation of FDP_A, B, and C explained in the previous section, the regression model obtained is:

FDP (Y, Final Mark) = 0.23 + 0.02*(FDP_A) +0.13*(FDP_B) + 0.81*(FDP_C)

Certainly (we are using the same variables that generate the FDP), the result of the F critical value (p = 0.000) indicates that the variables are significantly interrelated, and the coefficient of determination (R^2), which measures the value of model fit at 0.9911. To summarize, we can affirm that FDP_C activity (the project defense) is the main component that affects the FDP mark, as we can see in the model, but we also need to assess the weight of this mark supported by the different learning goals (LGs). Currently, half of the eight

learning goals weigh the 75% of the mark (LG1, 3, 4, and 7), and even the LG1 and LG3 reach the 45%.

This analytic approach has allowed us to identify the variables and the learning activities with more influence in the FDP. In future phases, it would be interesting to continue studying and modifying (in necessary cases) the weight of the activities, according the results of the next section, where we have identified and classified the main professional competences that FDP needs to incorporate.

3.3 Professional survey (Pre-Data)

The survey that provided the data pertinent to the present study was conducted by the Polytechnic University of Madrid (Technical School of Construction), and it was reviewed and validated by the Commission of the Conference of Directors of Building Engineering of Spain (CODATIE) [24]. The objective of analyzing the survey data was to identify the expectations of the businesses and the professional sector in order to improve the methodology of Building and Construction Engineering studies. As a starting point, the preparation and skills of today's students was assessed. The survey analyzes 22 variables, 15 specific (C#), and seven generic (GC#) competences that we have listed and presented in this section. The representatives of the companies included in the survey were required to rate each statement on a Likert scale ranging from 1 to 5. In addition, students were asked to complete the same survey in order to compare their responses (which reflected their perceptions of the level of preparation received) with the importance that companies give to the same competences.

The professional sample comprised of 92 companies, 72% of which were from engineering and architecture sector, and the remaining 28%were construction firms. Moreover, 93% of the participating firms were medium/small enterprises, and only 7% could be defined as big firms. When responding to the survey, the study participants were asked to evaluate specific competencies (C#), which are shown below, arranged by their relative importance (from the highest to the lowest) as determined by the professional world:

- C1: Knowledge of the basic principles of the legal system in the construction and the management regulatory framework and urban discipline.
- C2: Knowledge of the basic principles of the company's organization, the work organization, the production systems, and financial plans. Ability to perform market surveys, valuations, appraisals and real estate feasibility studies.
- C3: Capability to carry out the design, execution and maintenance of facilities.
- C4: Ability to apply knowledge of basic subjects (mathematics, statistics, mechanics, heat, electricity, acoustics, chemistry, and fluid mechanics) in the building context.
- C5: Aptitude for the calculation of structures and for directing their material execution.
- C6: Knowledge of the specific prevention regulations and the aptitude for drafting occupational safety, health plans, and building evacuation projects.
- C7: Capacity to assess the environmental impact and energy efficiency of buildings.
- C8: Aptitude for quality control management in the projects and the management of the quality of the companies.
- C9: Knowledge of constructive technologies and systems characteristics, their evolution and specific procedures for the control of project execution.
- C10: Knowledge of the characteristics of the building materials and the ability to set quality control standards.
- C11: Capability to schedule and arrange construction processes.
- C12: Aptitude for writing technical projects and documentation required for a project execution, according to regulations, as well as awareness of administrative procedures, management and processing in the building.
- C13: Ability to intervene in the rehabilitation of buildings, make proposals to prevent or resolve constructive pathologies and develop manuals and maintenance plans.
- C14: Proficient use of graphic representation techniques pertinent to the construction processes, as well as capacity for producing drawings and conducting geometric control of the project.
- C15: Capability to analyze and control costs of the construction process and prepare budgets.

In Table 4, the importance given by the companies to the competencies described above is contrasted with the level of preparation perceived by the students.

Using the same template, both students and company representatives were asked to rate the importance of certain generic skills. The labels used to display the results (GC#: Generic Competences) and their related competences are shown below, in descending order based on the relative importance:

- GC1: Foreign language proficiency.
- GC2: Capacity of entrepreneurship and innovation.
- GC3: Awareness of the importance of sustainability and social commitment.

Table 4. Specific competences average of Pre-study

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	Average
Professional importance (Pre)	3.5	3.5	3.6	3.6	3.9	4.1	4.1	4.2	4.3	4.4	4.4	4.5	4.6	4.6	4.7	**4.13**
University preparation (Pre)	3	2.8	2.4	3.1	2.7	2.8	2.5	2.9	2.9	3.1	2.9	2.7	2.9	3.6	2.6	**2.86**

Table 5. Generic competences average of Pre-study

	GC1	GC2	GC3	GC4	GC5	GC6	GC7	Average
Professional importance (Pre)	3.5	4.05	4.17	4.34	4.34	4.41	4.57	**4.20**
University preparation (Pre)	3	2.77	2.37	3.11	2.75	2.88	2.5	**2.77**

Table 6. Specific competences average of Post-study

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	Average
Professional importance (Post)	3.70	3.91	3.63	4.06	3.70	3.75	4.14	3.91	4.31	4.13	4.27	4.16	4.51	4.40	4.20	**4.05**
Standard Deviation	0.98	0.93	0.98	1.00	0.91	1.06	0.94	0.94	0.82	0.94	0.77	0.78	0.70	0.86	0.83	**0.90**
University preparation (Post)	3.11	2.84	3.387	3.51	3.63	3.49	3.09	3.42	3.73	3.72	3.69	3.53	3.39	4.17	3.84	**3.50**
Standard Deviation	1.07	1.25	0.97	0.91	0.86	1.00	1.26	1.06	1.04	1.03	0.84	1.17	1.22	0.88	1.03	**1.04**

- GC4: Ability to utilize information resources.
- GC5: Capacity for autonomous learning.
- GC6: Effective oral and written communication.
- GC7: Ability to work in teams.

Comparative analysis of the generic competences yielded results summarized in Table 5.

While competences listed above are only a subsection of the skills necessary for successful execution of practical projects, they were selected in order to facilitate comparative analysis. Our qualitative study identified 15 specific and further 7 generic competencies, which should be taken into account in the design of the Building Engineering Degree curriculum. Moreover, as the expectations from the industry do not align with the students' competency levels, there is a clear need to revise the current approach to their education. The main conclusion is that students possess theoretical knowledge but lack practical skills, as well as training on topics such as sustainability, management of the construction process, and the drafting of technical projects. In particular, a much greater focus should be given to the graphical representation through technological systems, such as Building Information Modelling (BIM).

It is also noteworthy that, while professionals identified five core competencies (C11 to C15), as shown in Table 4, students recognized only C14 as the one in which their training was adequate, while C15 was among the three competencies rated the lowest in terms of the preparation obtained. This pattern emerged when generic competencies were analyzed (see Table 5). This imbalance leads us to the realization that the current training and learning activities do not align with the professional needs of the sector.

3.4 Survey replication (Post-Data)

In order to identify the specific FDP activities that should be modified in order to equip the students with the professional skills deemed necessary by the industry specialists, we have conducted a replication survey to which 190 individuals responded, comprising of:

- 86 professionals (Average Age: 47.72, SD = 10.71, of whom 46 were self-employed, 31 worked for a private company, and 9 were public administration officials).
- 18 course instructors (that can also be considered professionals; AV: 49.53, SD: 10.20).
- 86 graduates or students (Av: 31.61, SD: 5.56, 27 of whom were still studying for a degree).

The results yielded by analyzing their survey responses are presented in Table 6, where they are sorted based on the criteria of the first survey.

To compare the results of the original and the replication survey, we have separated the responses provided by the professionals (Fig. 3) from those provided by the students (Fig. 4).

To estimate the probability that results are significantly similar, we conducted the Student's t-test, which was applied to the null hypothesis (H_o) that there are no differences in scores between variables. The findings revealed no statistically significant differences between professionals' responses given in the initial and the replication survey (P(T) = p two-tailed is 0.532). On the other hand, a statically significant difference in the responses given by the students in the two surveys were noted (P(T) = p two-tailed is 0.000). Our students perceive a better significance preparation (average of 3.50), than the students consulted in the first study (Av: 2.86).

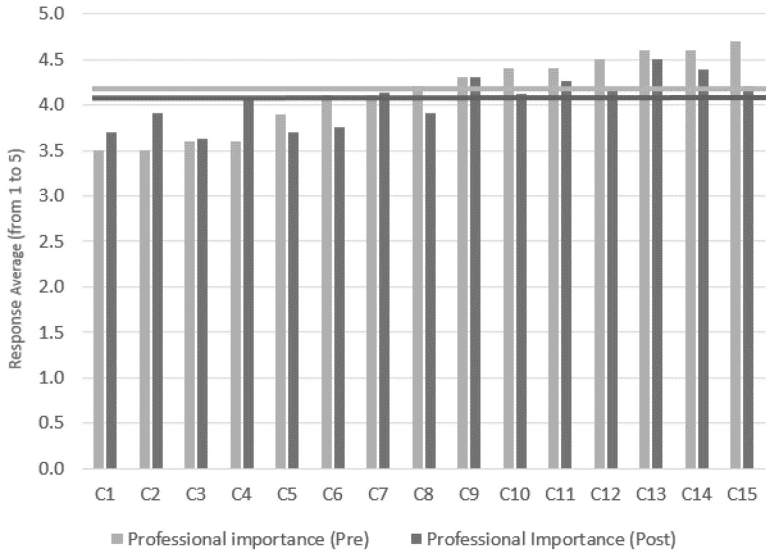


Fig. 3. Comparison of specific competences (professional view) between studies (Pre and Post-data).

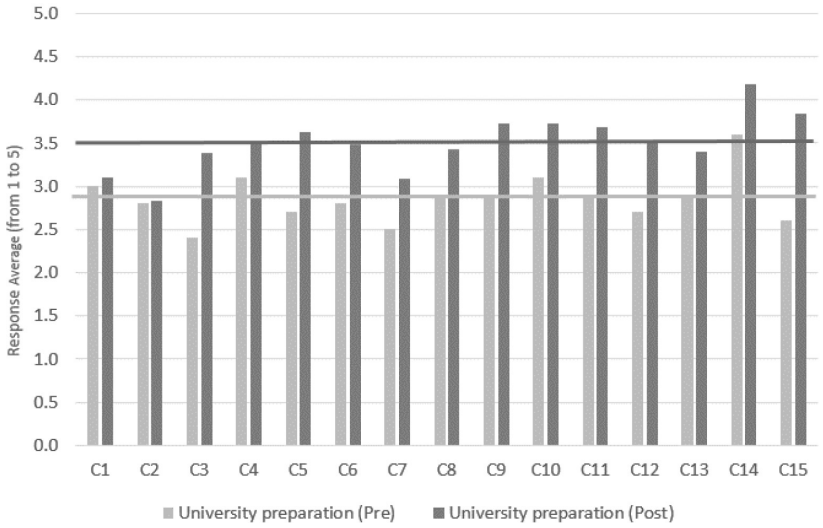


Fig. 4. Comparison of specific competences (students view) between studies (Pre and Post-data).

Table 7. Generic competences average of Pre-study

	GC1	GC2	GC3	GC4	GC5	GC6	GC7	Average
Professional importance (Pre)	4.16	4.33	4.27	4.14	4.52	4.51	4.60	**4.36**
Standard Deviation	0.93	0.87	0.85	0.83	0.70	0.68	0.62	**0.78**
University preparation (Pre)	2.63	2.96	3.13	3.66	4.02	3.14	3.92	**3.35**
Standard Deviation	4.18	1.32	1.26	1.00	1.03	1.43	0.98	**1.21**

On the other hand, in Table 7, we can observe the distribution of the survey results pertaining to generic competences.

Once again, Student's t-test was applied in order to assess the validity of the null hypothesis (H_o) that there are no differences in scores between variables. Once again, the comparison of responses given by professionals revealed no significant differences (P(T) = p two-tailed is 0.299), as shown in Fig. 5. Yet, a statically significant difference between the responses given by the students at the initial and replication survey was noted (P(T) = p two-tailed is 0.027), as shown in Fig. 6. Our students perceive a better significance preparation (average of 4.36), than the students consulted in the first study (Av: 2.77).

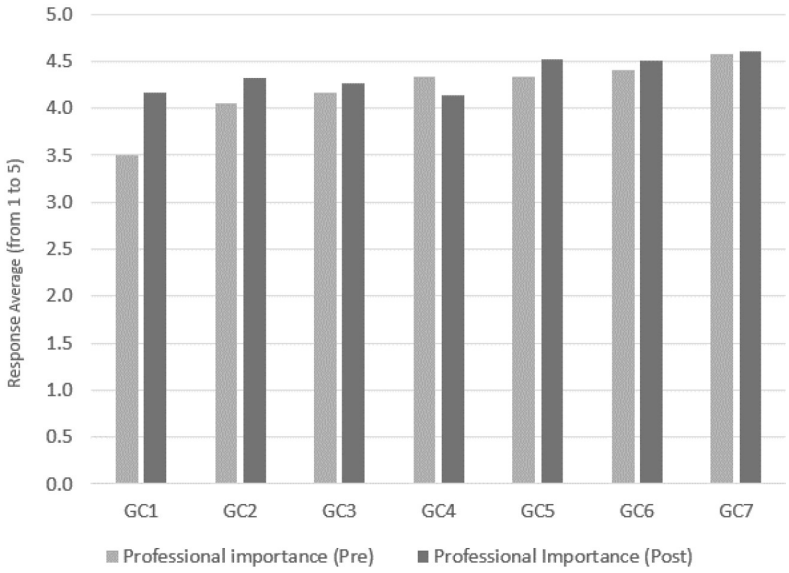


Fig. 5. Comparison of generic competences (professional view) between studies (Pre and Post-study).

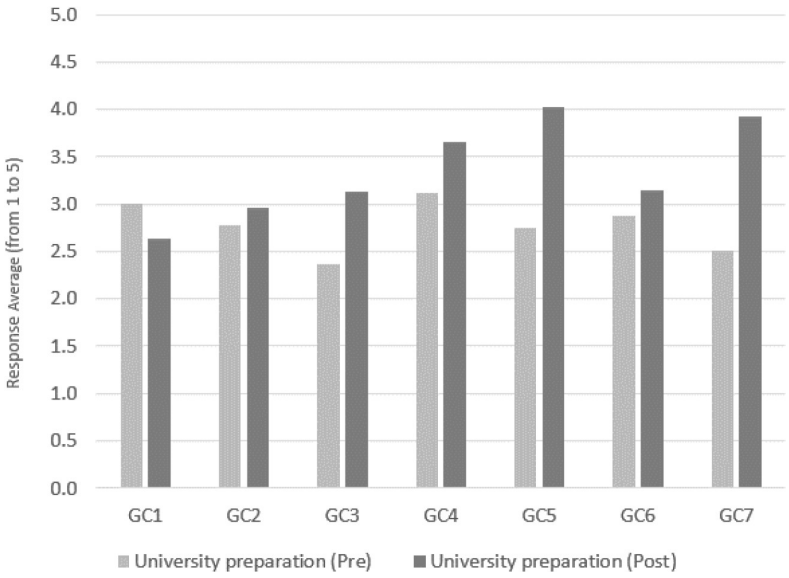


Fig. 6. Comparison of generic competences (student view) between studies (Pre and Post-study).

4. Discussion

The results obtained from the replicated generic competences survey reveal two significant aspects:

- At a professional level, the competences initially identified as the most significant were confirmed in the replication survey.
- Marked differences in the perceived preparedness by the students are noted, as those that responded to the replication survey felt better equipped for assuming professional duties upon graduation.

This last finding is directly linked to both the structure of the degree and the FDP, which indicates that the current structure is valid, at the expense of adapting it to the professional necessities for its optimization.

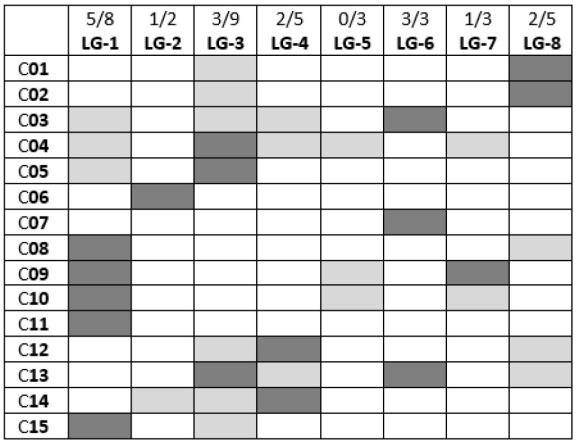
Similarly, the results pertaining to the general competences reaffirm that the current model meets its objectives, even though further improvements can be made to fully align the generic competences students possess with the expectations of the industry professionals. The correlation between professional evaluations is still strong (0.8712), and between the professional and the students' is 0.5587. This correlation is even stronger if we compare the professional Pre results with the students' Post evaluation, at 0.7997, which allows us to affirm that our students are well prepared for assuming professional duties in Spain, and specifi-

cally Catalonia. Nonetheless, their preparedness could be enhanced in order to continue to respond to the increasing demands of the profession and global economy.

Because the FDP is a compendium of skills and competences that the student must acquire (identified as LG in Section 3.1), a matrix shown in Fig. 7 was created, allowing the LGs to be related to the professional competences identified as the key prerequisites in Section 3.3. This exercise allowed us to identify the objectives that respond to the necessities of the sector, as well as those that do not and should be revised.

In Figure 7, we can observe that the general characteristics of the LGs correspond to the various competences required by the sector (C#). In particular, those with an indirect connection are marked in light grey, while the dark grey identifies a clear and direct connection. This allows us to visually note that the objective LG1 (which corresponds to the direction of construction execution, basic professional attribute of the Building Engineer) is correlated with eight competencies five of which are priority (C08, C09, C10, C11 and C15), while the objective LG5 is subject to secondary correlations (C04, C09, and C11) only. For the execution of this translation, the exercise explained in Section 3.1 is fundamental, where we establish a relation of the other LGs with the activities/exercises/tasks which the FDP is composed by.

Based on these relations, we can affirm that LG1 responds to the necessities of the sector mainly related with managing the quality of the construction works, knowing the constructive processes and materials, having the capacity to program the works, and specifically having the capacity to control the costs. This same objective has a secondary link to the knowledge of facilities, basic calculations, and execution of structures. On the other hand, objective LG5 is indirectly related to the following competences: knowledge of basic matters, knowledge of systems and constructive technologies, and knowledge of materials. These results allow us to argue that, in the current context of the sector, managing new technologies and the quality of the construction (LG5) are not particularly pertinent. On the other hand, objectives LG1 and LG3 correspond to the greatest number of competences required by sector companies.



	5/8 LG-1	1/2 LG-2	3/9 LG-3	2/5 LG-4	0/3 LG-5	3/3 LG-6	1/3 LG-7	2/5 LG-8
C01								
C02								
C03								
C04								
C05								
C06								
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C15								

Fig. 7. Relation Matrix between LGs and specific competences.

Based on these relations, we aimed to answer the following questions: Should we adapt the LGs to the requirements of the sector? Should we do it despite taking into account the casuistry of the search for immediate results? Conversely, should we bet for keeping LGs active, which, despite not being very demanded, configure the academic composition established by the norm? It seems reasonable to select the approach that would result in seamless knowledge transfer from academia to the industry, which can be achieved by changing the weighting of the LGs while retaining the course content, changing the content while keeping the current weighting unchanged, or changing both.

In all cases, we take for granted that we will consider whether to modify and adapt the methodology of the formative activities, and how we take into account the normative aspects that rule the current configuration of the FDP (ECI Norm, grade memory).

The decision of how to change or adapt, if necessary, certain educative activities to the professional necessities/competences is a field under continuous study and with previous contributions [25–27]. The competencies identified in every study are changing, and not all of them are assumable during the degree, but over a lifetime of professional practice, education and training [28]. We have found studies that have yielded both positive and negative responses from academics towards a competency-based approach to higher education. In a negative way the approaches seem ''too narrow... mechanistic and prescriptive''. On the other hand, there was also a significantly positive response: ''competencies based in education and training as benefiting higher education in clarifying intended outcomes of undergraduate programs, particularly in relation to workplace requirements [29].

Likewise, it is difficult to extrapolate the results of existing studies, even the present one, due to the disparity of attributions and professional competences according to the nation or geographical context [30–32, 38]. All of these proposals aim at identifying the aspects, which will allow the educative systems to modernize, identifying the structure of professionalism management system in construction framework, and suggesting the system of interrelation of basic programs of higher professional

education and professional retraining with professional communities in construction field. The most important professional abilities identified in the references studies [32, 33] are centered upon basic and transversal competences, such as: decision making (leadership), communicating (oral/written), managing information, planning work, motivation [36, 37]; as well as more specific competences as managing health and safety, assessing environmental risk factors or costs, etc. In any case, these examples are centered in the global shape of the studies, and not so much on the activity of the FDP, an aspect that distinguishes our job.

On the other hand, we cannot forget that the learning process and individual development of the student is just as important as the academic results of assessment. The process of matching the requirements of the employers with course provision is always difficult. For a degree such as Building and Construction Engineer, where there is such a diversity of employers, a wide variety of roles, and an ever changing business environment, this difficulty is exacerbated [33]. Based on the investigations which have proven that a student's interest, stress, learning productivity and academic achievement are quite closely related, it is necessary, in order to cause interest and to increase the learning productivity, to establish constant changes in the learning subject with regard to situational and individual interest.

Some new approaches following the previous ideas are related with new affective tutoring systems [34] closer to the students, their problems, and their project development, and other examples focused on the introduction of new technologies in order to develop the students' knowledge, to control their emotions, and to reduce their stress. In this last direction, the use and development of any type of electronic and mobile system [39], or any BIM technology applied for improving specific representational and managing competences in building and construction [40] are being worldwide fundamental initiatives [35], and in our case, they must be incorporated efficiently in the development of the FDP (currently established in a scheduled way, in specific subjects of the degree).

In addition, in our local case, it is important to take into account:

- The logic evolution of the normative parameters that took place throughout the last decade.
- Such as the adaptation to the number of credits established by the EHEA.
- The qualitative modification of the configuration of an executive project according to the Technical Code of Building.
- Finally, the professional requirements of an agent.

All of these changes have occurred in an environment with past crises, where personal abilities to value the competences can be as transcendent as the same competences.

Since all training activities and/or subjects including the FDP are composed of a definition of learning outcomes, assessment criteria, academic methodology, specific contents or themes, systems, and monitoring tools, the new relationships established as a result of the study data suggest a modification of one or several parts for a better adaptation to those results. For example:

- Case 1: identifying competences (such as C13, see Table 6), which would need reinforcement in the LGs. As observed in our study, while it is a competence demanded by the profession, students do not have the perception of being sufficiently qualified for the development of the same. In this case, the solution would be to increase the content/value of the rehabilitation in the FDP and/or to increase the number of FDPs based on rehabilitation or with thematic developments in pathological diagnosis and durability of the constructive solutions.
- Case 2: identify learning activities currently developed and under-represented in the competencies requested (LG5, see Fig. 7). In this case, it seems advisable to maintain the learning objective by reducing its teaching load and/or by making business pedagogy regarding the cross-sectional value of the same.

5. Conclusions

In this work, we have presented and related two main data: in the first one, using an academic analytic approach, we have studied and identified the main variables and learning activities that define the FDP mark. In second place, we have presented the results obtained from two surveys, the initial one conducted in the national context, and its replication conducted in the local context. With these surveys, we have identified the main professional competences that the labor market search in our Building Engineering degree students that they must have acquired when they develop their FDP. Comparative analysis of the survey responses indicates that, while the ratings provided by the professionals remained unchanged, a significant difference in the perceived level of acquired competencies was noted between the national and the local student sample.

In the discussion section, using the results of the surveys and our analytic data obtained from the FDP results in the last three years, we have established a new relationship with the activities and

defined LGs in the current FDP. This analysis allowed us to observe that some learning objectives and contents of FDP have little relevance to the sector professionals and their balance need to be improved. This led us to conclude that the FDP and its activities must be adapted for a better response to the business requirements. We also proposed a configuration that facilitates this adaptation throughout time and according to the evolution of the sector.

During the development of the paper, we have also presented the comparison between the generic competences demanded and those acquired by the students. Although in this case the correlation is much greater, we also conclude that several aspects should be enhanced, affecting the methodologies and academic resources. All these aspects, given their magnitude and impact, remain as future lines of work, since they need detailed study and implementation, and cannot be imminently supported either by the academic structure or by the current FDP developments in course.

Based on the data and proposals presented, the lines of work of the present study are based on implementation, analysis and replication. Initially, how to ponder and implement the proposed system will be studied during the next FDP meetings. Logically, this process needs a change in the structure of the whole subject, providing the necessary time and resources for the new weights of each activity and the follow-up by the students. The second line of action will focus on analyzing the relationship between academic variables of the FDP, learning activities and professional competences. In this field, and given the novelty of the study, AA and/or EDM techniques can be used to facilitate the FDP assessment using the main professional indicators. Based on the results of the proposed implementation and analysis, and as a third line of action, the method is planned to be replicated in the nearest schools or by FDP implementation system.

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