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Half a century of teaching-learning Physics for Architecture and Technical Architecture

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***Abstract*— The buildings of the schools of Architecture and Technical Architecture in Avenida de la Reina Mercedes were the first of a number of teaching buildings run by the University of Seville in its south campus. Although both centres began their journey in 1960 on a provisional basis in the former Brazilian Pavilion of the 1929 Ibero-American Exposition in Avenida de la Palmera, in the academic year 1966-67 the relocation and opening of these new schools occurred. Early in their teaching trajectory, the centres depended on the School of Architecture of Madrid, and in 1964, the schools became autonomous.**

It should be borne in mind that the model used in Spain in the construction sector regarding the organization of securities and the exercise of professions is a specific model that is not widespread in Europe. Here, the academic qualification directly enables the exercise of a legally recognized profession that has its own sphere of competence: a practice unheard of in other countries. Both the architect and technical architect of our country are technical professionals whose expertise and training, are based on ancient origins which have evolved through many vicissitudes, especially that of the latter profession. In the complex field of construction there are two basic tasks: to plan and to carry out work. There are also two functions that are assigned to technicians who are involved in these tasks: to design and to direct the work. An architect's professional assignments are to design and direct the work, and for a technical architect to be the director of the execution of the work, that is, to be the agent as part of the project management together with the architect, and to assume the technical function of directing the material execution of the work, and to monitor the construction and the quality of the buildings both qualitatively and quantitatively.

Over recent decades, the lecturers of these centres have developed their teaching role within the guidelines framed by five curricula, the latest being that of the European Higher Education Area (EHEA), where both Physics together with Mathematics have constituted a propaedeutic stage for the specific areas of training of these professionals, since the first discipline corresponds to the physical principles upon which rest the techniques and applications that students must take in their specialty subjects.

This academic year marked the 50th anniversary of the first promotion of architect and technical architect graduates from the two schools following the autonomy of the centres. The author of this paper analyses the evolution of the contents, the teaching methodologies, and the results of the evaluation of curricular material related to the discipline of Physics in each curriculum of the schools, with special emphasis on the last three curricula, and provides a comparison of the above aspects in the two neighbouring schools covering the last half century. The data provided enables conclusions to be drawn, and the changes these two degrees in Seville have been forced to undergo due to the Bologna process are analysed.

***Keywords*— Architecture, Building engineering, Technical training, Physics, Construction, Curriculum differences.**

I. INTRODUCTION

The general law of Management of Technical Sciences (1957) led to the creation of the Technical Schools of Architecture and Technical Architecture of Seville by decree of July 16, 1959. Until that date, a construction engineer or architect could only be qualified in the Schools of Madrid and Barcelona and in the polytechnic college of La Laguna. After the technical schools were established in Seville, others in Spain were also set up: Technical Architecture in Burgos (1962), Architecture in Valencia (1966), Technical Architecture in Granada and Valencia, and Architecture in Valladolid (1968), Technical Architecture in La Coruña

(1971), and Architecture in Las Palmas de Gran Canaria and La Coruña (1973), etc.

Classes began in the academic year 1960-61; in technical architecture with a selective course of initiation to expertise from Plan 57, which had to be passed in a maximum of two academic years (only with *pass* or *fail*) followed by three more academic years [1]. In 1962-63, a joint preparatory course based on mathematics, physics and chemistry was introduced for access for those with basic high school and industrial officer school qualifications. In the second and third years, *works organization* subjects were taught since the *urban planning* specialty was not taught in Seville. In architecture, teaching also began with compulsory subjects that included mathematics and natural sciences, that could be followed in Higher Technical Schools or in the Faculties of Sciences, followed by an introductory year in Architecture or Engineering, to be performed in Technical Schools, composed of extensions of mathematics, physics, drawing, and a group of subjects common to the teachings of the centre that should be taken within a maximum of two academic years, limited to the grade of *pass or fail* (Plan 57). After the introductory year, five years and a final written project (PFC) were needed to obtain the qualification. It was the Higher Technical School of Architecture of Madrid which initially coordinated the new centres.

While classes were held in the former Brazilian Pavilion (Fig. 1), the ministry managed the construction of the two new centres on the plots of the former regional pavilions from the Seville Ibero-American Exhibition of 1929, on the principal site of Avenida Reina Mercedes (south Campus). These buildings were designed by Fernández-Huidobro and Gómez-Stern.

In April 1964, the law of reorganization of Technical Education, which sought to advance the training of technicians in Spain increasing its number and by accelerating their learning process, was enacted. This meant that lessons taught in the technical colleges were reduced to five academic years, and three academic years for the technical middle colleges, which were intended to promote specialties.

Consequently, a new nationwide curriculum, Plan 64, (for Technical Architects in Execution of Works) was implemented in the academic year 1965-66 and which consisted of a first year of basic disciplines, followed by two years with specific disciplines for this career. Its validity was short and it was reformed with minor corrections in 1969. For Architecture, the study plan was based on five years [2], the first two years of an obligatory nature together with a common third year; the fourth and fifth years specialized in either Urbanism or Edification. Teaching was organized into new groups of university Chairs.

In general, one can speak of homogeneity among schools across Spain up to the curriculum 1975, in the pre-democracy of Spain, since, as a result of the general Education Law in 1970, each university and each centre began to enjoy some autonomy that over time would increase, resulting in a number of features that caused differences between schools. Later, the university reform law (LRU 1983) aimed to bring university education to a different social, political and legal framework of that existing in 1970, and included the creation of *a department* as the basic unit of teaching and research, and established them in accordance with their attachment to areas of knowledge. It was intended that the LRU also became the framework to break the rigidity of the system and to adapt the offers of qualifications to social demands and new technologies, while fulfilling other basic requirements, in harmony with EU requirements. In terms of contents, we find the core subjects imposed by the ministry of education, while each college can include its mandatory, optional and free configuration subjects (1998 Study Plan for Architecture and 1999 Study Plan for Technical Architecture).

The then Department of Applied Physics, assigned to the area of knowledge known as Applied Physics, was responsible since its inception in the academic year 1987-88 for the teaching of physics in all Technical Schools and Middle-Level Technical Schools of the University of Seville. In 2000, segregation into three departments occurred, mainly due to the increase in the number of lecturers and the transfer of the Higher Technical School of Industrial Engineering from the Reina Mercedes campus to Cartuja Island in 1997-98. This department is now called the Department of Applied Physics II, which is in charge of physics matters in the two technical schools: this constitutes our focus on the University of Seville in this paper.

II. Characteristics of the Two Teaching Centres

The design of the two buildings is modern and in tune with urban and compositional principles of the moment of conception. It is also necessary to understand the changing nature of these buildings, which has led to numerous extensions and changes of use, thereby significantly changing the initial projects. Their registration is symptomatic of the plurality of ways of understanding architecture in the last 50 years [3].

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Fig. 1 Opening ceremony of the Schools of Technical Architecture and Architecture of Seville at the Brazilian Pavilion, chaired by the then Rector of the University of Seville and other authorities.

Fig. 2 Logos on the 50th anniversary of each centre and on the first promotion of Technical Architects after its independence.

Unlike the School of Architecture and the degree in Architecture, the School of Technical Architecture has had several changes of name throughout its history. This centre was created in 1959, originally being called School of Building Surveyors (1960-1966) and later School of Technical Architects (1966-1972), University School of Technical Architecture (1972-2002) after joining the University of Seville 1972, through the decision of centre’s own board, School of Technical Architecture (Building Surveyors).

Following adaptation to the European Area for Higher Education, since the 2010-11 academic year, the centre has been renamed the Higher Technical School of Building Engineering. Throughout its history, its qualifications have also been known as Building Surveyor, Technical Architect, and Graduate in Science and Building Technology in the latest study plan after the Bologna process. This has been reflected in the logos of the schools on the occasion of their 50th anniversary (see Fig. 2).

III. Features of the Degrees Presented

A. Architecture

In our country, architecture is conceived as a generalist discipline of technical and artistic nature characterized by its contribution to the transformation of the physical environment on all scales through the design and management of implementation of buildings and urban arrangements of all kinds. The presence of a profession dedicated to this activity has been documented for 45 centuries, the legal rules governing their performance for 37, and, for the last 26 centuries, the title for accrediting such exercise, recorded in a written way six hundred years after the acquisition of knowledge and skills were needed. Learning systems in architecture were developed in medieval Europe and were successively and profoundly renovated in the Renaissance, in the seventeenth century, in the Age of Enlightenment, and in the period between the two world wars of the twentieth century.

In Spain there has been the official degree of architect associated with an academic background in an enabling institution for professional practice since 1757, and a first centre which imparted its teachings with a technical nature since 1844 (Madrid), in which urban studies began to be integrated in 1864.

This long history guarantees the ability of the degree to renovate itself yet again, now adapting itself to the requirements of society at time and of the culture and contemporary sensibility, to the rapidly changing and diversified nature of technique, and to the European Higher Education Area. The degree must also collect the legal powers granted to current Spanish architects and ensure the acquisition of their specific skills (in particular, those that enable the depth of their technical knowledge to remain), in which lies international prestige and therefore presents advantageous market competition in the European work market [4].

Six study plans have framed the teaching qualification in this half century of architects at the University of Seville (57, 64, 75, 98, 2010 and 2012 study plans). Their essential characteristics are shown in Table I. For a more thorough discussion, the reader is referred to reference [2].

B. Technical Architecture

During the Middle Ages and the Golden Century, in our country, the traditional organization of construction work was based on a hierarchy of tasks and duties. Every major building had a team of officials and labourers led by a master builder or surveyor, who, in some cases and depending on the importance of the construction entity, was under the command of an older master. The work of a Building Surveyor focused primarily on overseeing public work, on repairing walls, royal houses and public buildings, as well as monitoring housing so that they would be in accordance with the ordinances.

From 1757, the newly established San Fernando Academy of Fine Arts in Madrid would be the institution to grant degrees, whereby, in Seville, this would be the Academy of the Three Noble Arts, in which two technical architects became directors. At this time, the figure of the building surveyor can be clearly distinguished; hierarchically this is located in the career ladder above master-builders and at a lower grade to that of older master or architect. However, the suppression by the government, due to certain territorial disputes in 1854, of the figure of older Master, imposes a new figure of technical architect, taught since then in academies of noble arts. This decision would not be well received by older Masters, thus this figure was re-implanted in 1857 (Moyano's Law), with the same rights as technical architects. The controversy continued in 1871 when the competences of technical architects were suspended, but this figure was again restored and permanently, by the Royal Decree 20th July, 1895.

Between the years 1902-1912 technical architects characteristics were defined broadly, albeit unsatisfactorily, culminating with a Royal Decree in 1919, in which technical architects are considered as auxiliaries and assistants of an architect, and are mandatory in works of the State, county or municipality, and can lead building work in those places where there was no architect or where the budget of the building was below a certain amount. In turn, technical architects could lead the repairs of buildings on the condition that the structure and arrangement of their bricks and reinforcement and the appearance of their facades were not altered.

However, the decree of 16th July 1935, in force now in some of its measures, would really define the powers of the technical architect [5, 6], who is deprived of any planner capacity and is conceptualized as the director of the physical implementation of the building work. This same decree established the obligation of the existence of a technical architect for every architect. At the same time, the Schools of technical architect were reorganized, to be dependent on the Schools of Architecture.

In the complex field of construction there are two basic tasks, to design and to carry out work, and there are two functions that are assigned to technicians who are involved in them: to design and to direct the work. The law on building regulations from 1999 stipulates that the professional attribution of design and direction of the work corresponds to the architect, and consolidates the technical architect as the director of the execution of work of architecture, that is, to be the agent as part of the project management together with the architect, and to assume the technical function of directing the material execution of the work, and to monitor the construction and the quality of the buildings both qualitatively and quantitatively.

IV. SUBJECTS RELATED TO PHYSICS IN TECHNICAL ARCHITECTURE AND ARCHITECTURE STUDY PLANS

Physics tries to formulate general laws about the behaviour of nature, since it corresponds to the establishment of the physical principles on which lie techniques and applications that students of architecture and technical architecture should study in the subjects of specialty in their degree. The justification for their inclusion in the curricula of these two degrees comes under the requirements of the general guidelines of both degrees, as a basic subject which provides the knowledge required by other technical disciplines, not to mention the methodology and scientific-rational attitude that serve as their substrate [7].

This teaching paper is proposed as a continuation of the analysis conducted for the Higher Technical School of Architecture, where the author currently lectures, by implementing the methodology used in that work [2] to the neighbouring Technical Architecture School. The same department (Department of Applied Physics II), to which the author belongs, also exists in Technical Architecture School, and is entrusted with the teaching of physics subjects in both technical schools of the University of Seville.

Tables I and II summarize the characteristics of the various curricula that have taken place in the schools of Architecture (Table I) and of Technical Architecture (Table II) of the University of Seville in this half century: name of degrees, number of academic years, specialties, organization for weekly teaching, credits, and ECTS credits, character of the subjects, and in the last lines of the respective cells (in bold) the names of the subjects of physics, the academic year which is taught, subject type and its temporary nature.

It should be mentioned that, regarding the 1975 and 1998 curricula, there has been a sharp reduction in contents, especially in the new degree of architecture. Regarding the reason for the close proximity of the last two plans of architecture, it should be mentioned that the 2010 architectural curriculum arises at the juncture of the Spanish university adaptation to the guidelines of the European Higher Education Area (Bologna) and as a conclusion of reflection on the previous 1998 curriculum. Its generalist profile of an architect is recognized to provide students with the most suitable skills and qualifications to practise the profession of architect.

The plan is set into 300 ECTS plus a final degree project of 30 credits (PFC) under the designation of Graduate of Architecture; this is structured over 5 academic years with the PFC segregated into the sixth year. This plan took effect from 2010-11 academic year.

TABLE I.
RELEVANT DATA FROM THE VARIOUS STUDY PLANS FOR AN ARCHITECT DEGREE AND THE SUBJECTS OF PHYSICS (IN BOLD) IN EACH STUDY PLAN.

1957 Architect Obligatory Course in sciences (CS) Preparatory course (CI) 5 years + Final Degree Project PFC Different timetable hours each year Annual subjects **General Physics** (CS) **Physics** (CI) **Extension of Mathematics and Mechanics** (1st) Annual
1964 Architect 5 years + PFC 2 first years of obligatory nature Specialities of Edification or Urbanism Same timetable hours each year Annual and quarterly subjects **Physics** (1st) Annual **Extension of Physics** (2nd) Annual
1975 Architect 6 years +PFC Specialities of Edification or Urbanism Different timetable hours each year Weekly teaching hours depending on the year All subjects of annual nature **Physics I** (1st) 5 hours per week **Physics II** (2nd) 3 hours per week **Physics III** (3rd) 4 hours per week
1998 Architect 5 years + PFC 450 credits 3 Curricular lines 90 credits a year 30 weekly teaching hours Subjects: Annual and quarterly nature Trunk, mandatory, optional and free configuration subjects **Physics I** (1^{st} year, 2^{nd} quarter) Trunk 6 credits **Physics** (2^{nd} year, annual) Mandatory 9 credits **Acoustics and Energy Exchange in Buildings (ACU)** (4th year, 1^{st} quarter) Optional 4.5 credits
2010 Degree in Architecture 5 years + PFC 330 ECTS 60 ECTS credits per year/30 per semester 20 weekly teaching hours All semi-annual subjects Based on 5 subjects of 6 ECTS per semester **Physical Fundamentals of Structures (FEE)** (1^{st} year, 1^{st} semester) 6 ECTS **Physical Fundamentals of Facilities and Conditioning (FFIA)** (2^{nd} year, 2^{nd} semester) 6 ECTS **Acoustics applied to Architecture and Urbanism** (5^{th} year, 1^{st} semester) 6 ECTS **Energy and Sustainability in Architecture** (5^{th} year, 2^{nd} semester) 6 ECTS
2012 Degree in Fundamentals of Architecture and Master´s degree in Architecture Degree 5 years + Final Degree Project (TFG) Master 30 ECTS credits + PFC (60 ECTS c.) 60 ECTS credits per year/30 per semester 20 weekly teaching hours All semi-annual subjects Based on 5 subjects of 6 ECTS per semester **Physical Fundamentals of Structures (FEE)** (1^{st} year, 1^{st}

semester) 6 ECTS **Physical Fundamentals of Facilities and Conditioning (FFIA)** (2nd year, 2nd semester) 6 ECTS **Acoustics applied to Architecture and Urbanism** (5th year, 1st semester) 6 ECTS **Energy and Sustainability in Architecture** (5th year, 2nd semester) 6 ECTS **Participation in TFG and in Extensions of subjects in 6th year**

However, in July 2010, the Ministry of Education changed the law, and studies of architecture had to be restructured to adapt to the new context of a degree with 300 ECTS (5 years including a final degree project) and a Master's degree with 60 credits spread over 30 ECTS for intensification with specific teaching contents and 30 ECTS of final project in the sixth academic year. The qualification received in the master's degree is which enables to the practice of the profession. These guidelines correspond to the new teaching curriculum called Plan 2012. It entered into force in the Higher Technical School of Architecture (ETSA) in Seville in the current academic year 2013-14, with both curricula coexisting due to the similarities of contents and organization, except for the sixth year. The qualification obtained with this new curriculum will be a degree in Fundamentals of Architecture (level II), and a Master's degree in Architecture (level III of European studies).

As a general feature of technical architects in the various curricula (Table II), in the 57 and 64, curricula, subjects of physics were taught in the first two academic years, from 1977 and 1999 curricula, they are concentrated in the first year although with more weekly hours or credits. In the new degree, following the guidelines of the European Higher Education Area (Bologna), physics subjects are again fragmented into two physics courses, in part motivated by the increase of the total course by one academic year as happened in the curriculum 57.

TABLE II
RELEVANT DATA FROM THE VARIOUS STUDY PLANS (CURRICULA) OF TECHNICAL ARCHITECT IN PHYSICS SUBJECTS (IN BOLD) IN EACH CURRICULUM.

1957 Expert Building Surveyor Obligatory course of initiation to Building Surveyor (CSI) 28 hours per week Preparatory course + 3 years Different timetable hours per year All subjects of annual nature **Physics** (CSI) **Extension of Physics** (CP) **General Mechanics** 1st year, Annual
1964-1969 Technical Architect in execution of works 3 years + Final Degree Project (TFC) Specialities of Organization of Works or Facilities Same timetable hours each year Same weekly teaching hours Subjects of annual and quarterly nature **Physics** (1st year) Annual **Extension of Mechanics** (2nd year) Annual
1977 Technical Architect 3 years + Final Degree Project (TFC) Specialities of Organization of Works or Facilities Different timetable hours each year Different weekly teaching hours: 41 hours per week in 1st year 33 in 2nd and 34 in 3rd and in the two last years one optional subject All subjects of annual nature **Physics** (1st) Annual, 5 hours per week
1999 Technical Architect 3 years + Final Degree Project (TFC) 250 credits 225 trunk, mandatory, and optional+ 25 free configuration +TFC TFC is included in the credit computation but it is necessary to have passed the preceding credits. Subjects: Annual and quarterly nature **Physical Fundamentals of Technical Architecture** (FFAT) (1st year) 12 credits Annual
2009 Degree in Science and Technology of Edification 4 years + TFC 240 ECTS 60 ECTS credits per year/ in two equal semesters 20 weekly teaching hours All subjects of semi-annual nature Based on 5 subjects of 6 ECTS per semester **Physics I: Mechanics** (1st year, 2nd semester) 6 ECTS **Physics II: Fundamentals of Facilities** (2nd year, 1st semester) 6 ECTS

Regarding the teaching organization in the 1977 technical architecture and 1975 architecture curricula, student groups were numerous and coincided for theory and problems; in the 1999 and 1998 curricula, respectively, from the two schools, theoretical groups were numerous, with students numbering around 90, which were fragmented into three groups (~30 students) for practical classes. In the 2009 curriculum of the now School of Building Engineering, there are 12 teaching groups in the first year and 8 in the second year, although given the large number of students enrolled in this school, groups especially in the first year tend to be very numerous. In the Higher Architecture School, the severe reduction of credits for the qualification in the new degrees of the Bologna Plan has allowed, at zero teaching cost, the implementation of 14 teaching groups in all years at 25 students per group. These facts will become essential in discussing the results of the evaluation later.

As for teaching methodology, it is a common characteristic for the first two curricula in technical architecture (77 and 99 curricula), and architecture (75 and 98 curricula) that all lessons were lectures. As a new feature in the 99 and 98 curricula for teaching physics, laboratory practical classes appeared, where the students became responsible for working in pairs, for taking the corresponding experiment data, and properly answering a series of questions that were asked. In the 99 curriculum of technical architects, laboratory practices were carried out on a voluntary basis although attendance was largely the norm. In the 98 architecture curriculum, laboratory attendance was mandatory. In this respect, it is worth mentioning the major effort made by the teachers of the department to prepare suitable and updated technological format for the teaching material for all the physics subjects [8-14]. In the Bologna curricula, laboratory practices persist from the preceding curricula together with other new teaching equipment, and in both degrees they are of mandatory attendance.

Until the introduction of the Bologna degrees, the evaluation method consisted of passing all the partial exams of the subject (until September in the case of technical architecture, and until June in the case of architecture for an annual subject, or only one partial exam in the case of a quarterly subject) or alternatively passing the final exam. Ratings of laboratory practices, with continuous assessment method constituted 10% of the final grade. It should also be mentioned that these partial and final examinations were held with all groups together outside teaching hours, and therefore had a multitudinous character.

The same assessment procedures have persisted in the degree of Science and Building Technology in the EHEA, since there are common official written exams (consisting of theoretical multi-choice tests and problems in a similar form to those in the previous curricula) which are common to all groups and are outside teaching hours. These exams are independent of those set by each teacher who can include other aspects of continuous assessment in their teaching plan. As a general feature class attendance is very scarce.

However, the teaching organization of architecture has changed dramatically since the introduction of Bologna degrees for several reasons:

1. Every subject has a workload of 6 ECTS credits per semester, and hence every subject should provide a non-attendance workload equivalent. This benefits physics, for which this was excluded in the previous curricula.

2. Each lecturer is put in charge of a small number of students per class (25-30 students) which allows a natural way to introduce a more direct teacher-student relationship by seeking their active participation and enabling innovative methods of continuous assessment [15].

3. The rationalization of the weekly load of classes carried out by ECTS credits has enabled the student of this curriculum (20 hours per week at the rate of four hours daily) to have time for personal work, which is crucial in learning this discipline, and that supposes a great method of active learning, since it forces the student to make judgments and decisions [16].

The difficulty found due to the absence of digitized data of curricula, syllabuses, and proceedings corresponding to earlier curricula of 1998 and 1999 should be noted.

V. Results and Discussion

As shown in the introduction, the degree of technical architecture has undergone several name changes in the various curricula, in the following discussion for simplicity we keep the common name for all curricula as *Surveyor* or *Technical Architect*, interchangeably.

Given the dependence of the two schools of Seville on the School of Madrid in their early years (curriculum 57), and the difficulties encountered in obtaining the results of the evaluation of physics subjects from curriculum 64 in the degree of technical architecture (preparatory course and obligatory subjects) and subsequent rearrangements (1969 and 1971), a comparison of the results of only the last three curricula of building engineer and the last three curricula of architect has been carried out: more explicitly between physics subjects of the 1977 curriculum of technical architecture and the 1975 curriculum of architecture; between the 1999 curriculum of technical architecture and the 1998 curriculum of architecture, and between the 2009 curriculum of technical architecture and the 2010 and 2012 curricula of architecture.

For this comparison, data has been extracted from the records provided by the secretaries of the respective centres, for June and September in the same academic year, as specified in each figure caption.

Due to variety in the number of subjects related to physics in the two degrees, (for example, in subjects of architecture, there were three courses of physics in curriculum 75, while for technical architecture there was only one course (curriculum 77)), a comparison between the most similar subjects in contents, time duration, and weekly charge or credits is carried out (see Tables I and II).

At the top of Fig. 3, results from the grade records (proceedings) corresponding to the single subject of Physics for students of technical architecture of the 77 curriculum, and at the bottom for the first-year course of the 75 curriculum for architecture, Physics I, are shown. On the left-hand side of the figure, data is for the academic year 1990-91, and on the right-hand side for 1994-95. It can be noted from this figure that both degrees have a very high number of enrolled students, with an even greater number for technical architecture, and that the results of assessment are very similar, especially for the 90-91 academic year, with a success rate of 26.8% in technical architecture and 26.7% in architecture, and unsuccessful performance in both degrees of 73.2% (considering failures and non-attendance), with a slightly higher distribution of non-attendance by students of building surveying (50.4%) than in architecture (47.8%), and in contrast less failure (22.8%) in building surveying and more (25.47%) in architecture.

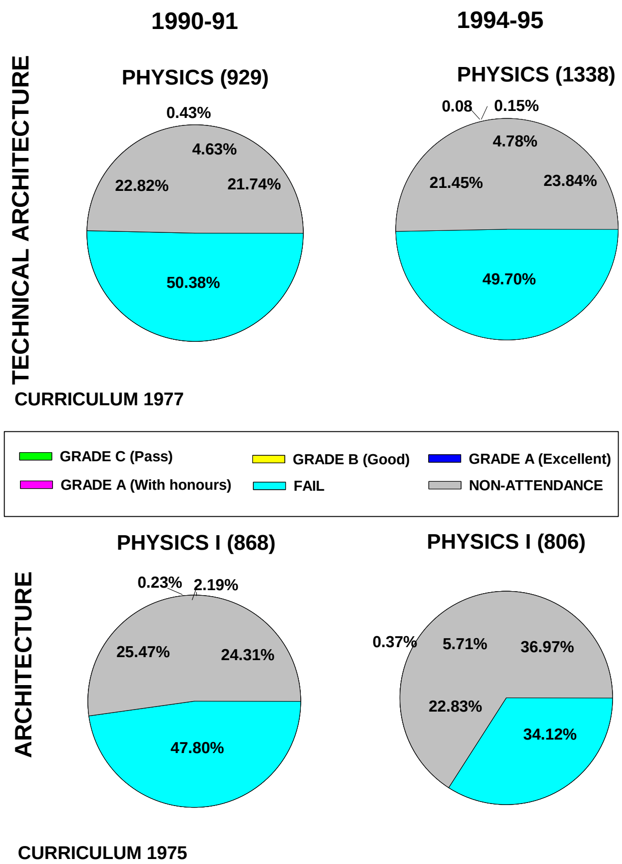

Fig. 3 (Top) Data on the distribution of grades for the first-year subject *Physics* for Technical Architecture, curriculum 1977. (Bottom) Data on the distribution of grades of the first-year-subject *Physics I* for Architects, curriculum 1975. On the left, data for the 1990-91 academic year, and on the right for 1994-95, in both cases. Enrollment numbers in brackets next to the name of the subject.

Furthermore, the percentage of outstanding qualifications and excellence is low in the two degrees. That same distribution persists in the academic year 1994-95: technical architecture (top right-hand-side pie chart) with a 28.8% rate of success and 71.1% percentage of non-attendance and failure. In the same academic year, architecture presents more optimistic results with 43% success and 57% of unsuccessful performance.

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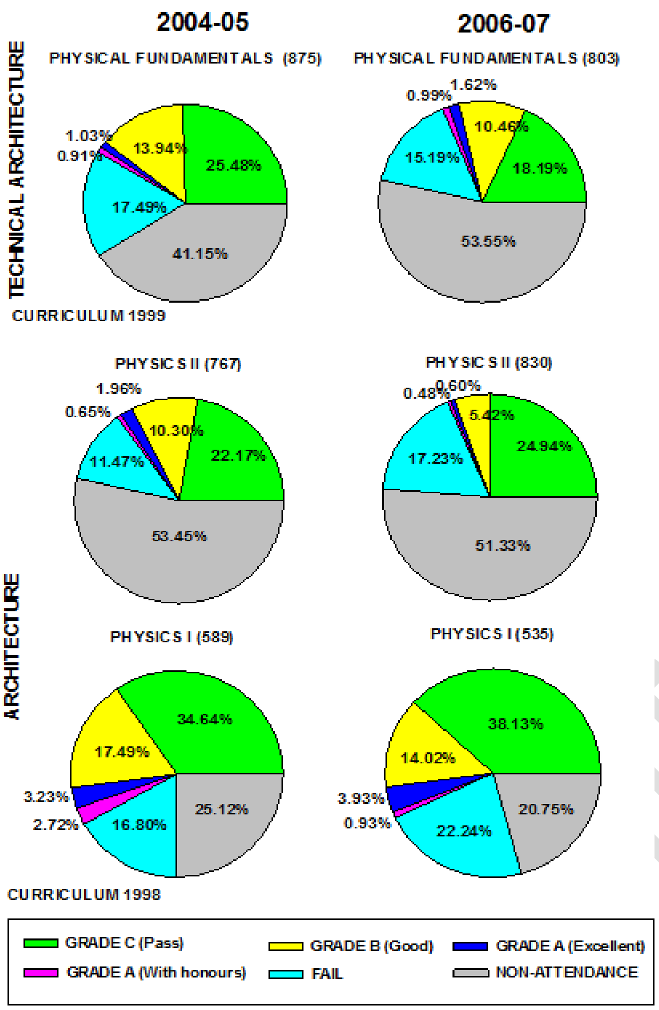

Fig. 4 (Top) Data on the distribution of grades for the first-year subject *Physical Foundations* of Technical Architecture, curriculum 1999. (In the middle) Data on the distribution of grades for the second-year subject *Physics II* for Architects, curriculum 1998. (Bottom) Data on the distribution of grades for the first-year subject *Physics I* for Architects, curriculum 1998. On the left, data for the 2004-05 academic year, and on the right for 2006-07. Enrolment numbers in brackets next to the name of the subject.

In Fig. 4 at the top, the results of the *Physical Fundamentals* of Technical Architecture (1999 curriculum) are shown, and in the middle those of the subject of *Physics II*, 1998 curriculum of architecture, for the sake of comparison. In this case, we have compared the results of a first-year subject in building surveying (12 credits, annual) with a second-year subject (9 credits, annual) and both with a similar number of students enrolled. The results of the topic equivalent to the first-year subject in architecture correspond to a quarterly subject of 6 credits whose results are shown in the lower part of Fig. 4, with a distribution of grades that is very different to the two mentioned above, and with significantly fewer students enrolled, as will be discussed later. It can be seen that there is a large quantity of non-attendance to these subjects: 41.15% in *Physical Foundations* in 2004-05 rising to 53.55% in 2006-07; and in *Physics II* for architects, the statistics are very similar at 53.45% in 2004-05, and 51.33% in 2006-07. Regarding the percentage of success, this is 41.36% and 31.26% respectively in the two academic years studied for technical architecture, and 35.08% and 31.44% in *Physics II* for architects. The unsuccessful performance of the topic (considering the sum of failures and non-attendance) is very low at around an average value of 65% students who fail or do not attend the subject in either of the two degrees.

The results of the assessment of the subject *Physics I* for Architects (Fig. 4 bottom) indicates that the percentage of success of this subject is higher than the other two subjects of the same figure, with the two academic years remaining at around 57%. The lower number of students enrolled in this course is also noteworthy, whose reason may be influenced by the different access quotas in the two degrees, although we believe that the main reason is the non-existence of a large number of repeaters from previous years. A greater number of grades of excellence and honours than the above subjects of Fig. 4 are also worth mention.

In order to conclude the analysis of the curricula in the study of these two parallel degrees, in Fig. 5 the results of the first-year subject of the degree in Science and Building Technology and degrees in Architecture and in Fundamentals of Architecture are compared for their respective subjects of physics: both have 6 ECTS credits although in different semesters, as detailed in Tables I and II. It can be noted that the number of students enrolled in Architecture is about a half that of the degree of Science and Building Technology and the percentage of passes (including grade C, B, and A, which we call *success*) is significantly higher in the degree of Architecture: in 2011-12, 28.83% for Mechanics, and 72.31% for Physical Fundamentals of Structures (FFE) and in 2012-13, 29.19% for Mechanics, and 58.13% in Physical Fundamentals of Structures (FFE) with a higher proportion of excellent grades in this last degree.

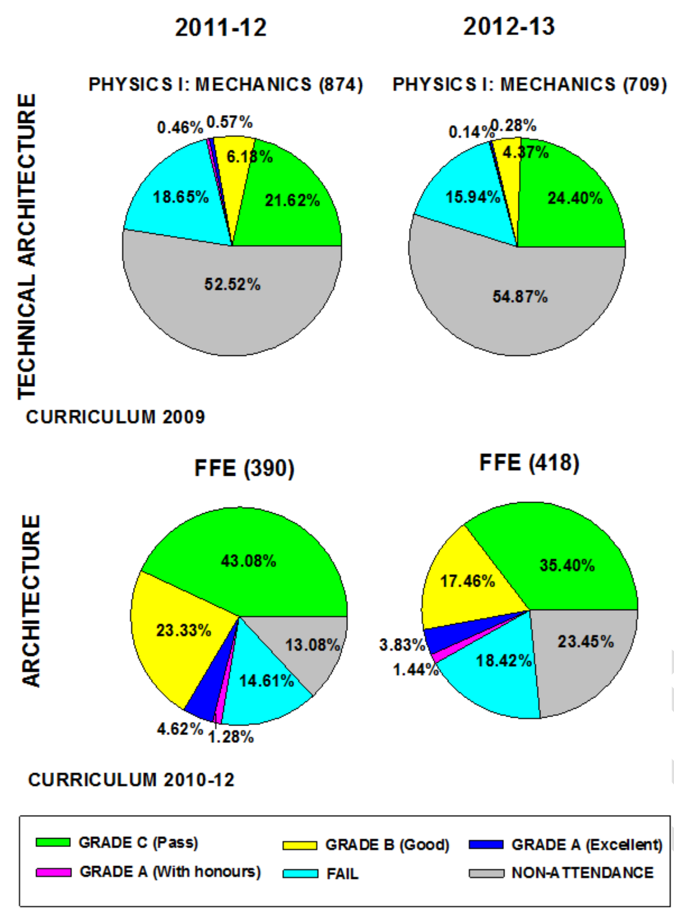

Fig. 5 (Top) Data on the distribution of grades for the first-year subject *Physics I: Mechanics* of the Bachelor`s degree in Building Science and Technology, curriculum 2009. (Bottom) Data on the distribution of grades for the fist-year subject, *Physical Foundations of Structures (FFE)* of the Bachelor`s degree in Architecture. On the left, data for the 2011-12 academic year, and on the right for 2012-13, in all cases. Enrollment numbers in brackets next to the name of the subject.

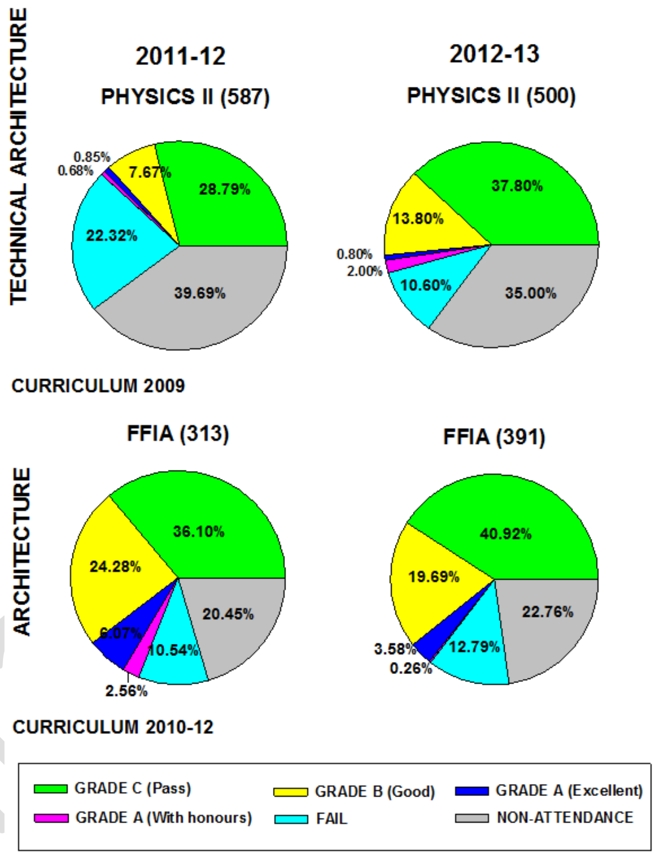

Fig. 6 (Top) Data on the distribution of grades for the second-year subject *Physics II: Fundamentals for Installations* of the Bachelor`s degree in Building Science and Technology, curriculum 2009. (Bottom) Data on the distribution of grades for the second-year subject *Physical Fundamentals for Installations and Conditioning (FFIA)* of the Bachelor`s degree in Architecture. On the left, data for the 2011-12 academic year and on the right for 2012-13, in all cases. Enrollment numbers in brackets next to the name of the subject.

As for the results of the subjects taught during the second-year Physics II: Fundamentals of Installations in the degree of Science and Building Technology, and Physical Fundamentals of Installations and Conditioning (FFIA) in the degree of Architecture and Fundamentals of Architecture, diagrams displayed in Fig. 6, show that the percentage of success is greater in the degree of Architecture, which remains above 60% in the two academic years analysed, and the large percentage of outstanding and remarkable grades in the degree of architecture.

In contrast, in the year 2011-12, the percentage of success in the degree of Science and Building Technology is 38%. It also highlights the greater number of non-attendance in this last degree of approximately 40% compared to the school of architecture which stands at 23%.

In summary, on the basis of the above results, we note that, in general in the first two curricula for each of the two degrees, *Physics* is a basis subject that many students fail to accomplish or in the majority of cases they fail to study regularly. In the case of architecture, students generally devote their best energies to projective or graphic materials which undergo continuous revisions, and to projects that must be successfully created through supervised work throughout the year. The fact that the weekly load or annual credits for these materials was very high in the first two curricula analysed (8 to 10 teaching hours per week or ~ 24 credits) is why the work required was very extensive. For technical architecture, the failure or abandonment of this subject may be due mainly to a low and varied previous level of access qualification (access was permitted without the necessity to pass an entrance examination or with only medium level of vocational training).

VI. CONCLUSIONS

In all curricula, both for Technical Architecture and Architecture, a generalist orientation leading to a unique degree regardless of specialty has been adopted. The contribution of *Physics* in the training of architects and technical architects is both for the contents, which should enable support for subsequent applications in specific areas of architecture and construction, together with the methodology, which promotes intellectual abilities on which rational decision-making is based.

Therefore, we can conclude that, in both these neighbouring degrees at the University of Seville, which are complementary in their professional practice, as far as the subjects of physics are concerned, the trend has been very similar, and only in the latest curriculum in these two schools, designed for adaptation to the European Higher Education Area, are the results significantly different of the assessment and the number of non-attendances, in the sense of abandonment, for the two subjects of physics that exist in each school in the first and second years. In the first year for *Mechanics* in the School of Building Engineering, figures are 52.5% of non-attendance, and for FFE in architecture, this number is 13% with a higher number of B and C grades. In the second year differences also persist, although with lower differences than in the first year, with a higher number of non-attendance at the school of Building Engineering and greater performance of the physics subjects in the School of Architecture: 69% versus 38% in the year 2011-12.

Although more years must elapse for statistical conclusions to be extracted by handling more data on the factors of influence on more successful results in academic performance, we believe that, as far as physics subjects are concerned in the degree of Architecture in relation to the degree of Science and Building Technology the following facts are meaningful:

- The severe reduction of weekly teaching hours and credits in the degree of Architecture has significantly affected this area, and consequently the assimilation of knowledge by students is lower, although they must maintain the same professional responsibilities as in previous degrees.
- Subjects all have a workload of 6 ECTS a semester, and hence all materials should provide a non-attendance workload equivalent; this benefits physics, which had no equivalent workload in the latest curricula of architecture.
- In architecture, all courses are divided into 14 teaching groups with 25-30 students per group on average, whereas there are 12 groups in technical architecture with 80 students per group on average. In the first case, this small number of students per class enables the lecturer to introduce a more direct lecturer-student relationship in a natural way in order to seek their active participation and thereby enabling innovative methods of continuous assessment in addition to written tests [15].
- Streamlining carried out in the weekly teaching load by ECTS credits has allowed students of this curriculum (20 hours per week at the rate of four daily) to have time for personal work, which is crucial in learning this discipline, and is a great method of active learning, since students are forced to make judgments and decisions [16].

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