Evolution of Computer Education in Spain: From Early Times to the Implementation of the Bologna Agreement

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Abstract: This paper intends to present a short overview of the evolution of computer education in Spain since the initial teaching in this domain to the current works to adapt it to the European Higher Education Space (EHES) from the point of view of somebody that has been involved and has directly participated in most of the steps of this evolution.

Keywords: Computer science education, Spain, Bologna agreement.

1. Remote Precursors

It is not here the correct place to talk about the precursors of computing machines but at least it is convenient to mention Ramon Llull (Raimundus Lullius) who in the XIII century invented several logical machines oriented to convert the Muslims to the, for him, truth religion, and Leonardo Torres Quevedo and Esteve Terrades who in late XIX and early XX centuries built several analog machines to solve complicated analytical calculations.

2. Early University Courses: Decade of 1960s

At university level, just the *Universidad Complutense de Madrid* had an Automatic Computation speciality with some courses on basic computer architecture and on programming, common to the curricula of Mathematics and Physics. The Industrial Engineering Schools had a course on Computers which mainly explained the basic Von Neumann architecture and the FORTRAN language.

In March 1969, the Ministry of Education created in Madrid the *Instituto de Informatica*, [5] a strange organization, without any contact with the university and following a strange curriculum: the students earned a different title after each one of the five years of studies after secondary education. With these degrees it was intended that people who earned them were ready to develop professional tasks in industry and companies. It is easy to understand the difficulties of simultaneously giving a solid background and the practical knowledge associated to each degree.

In October 1967 was created in Barcelona the *Asociación de Técnicos de Informática* that developed an important educational task (mainly courses on data structures, basic computer organization, programming languages, operating systems, etc.) oriented to give a computer science background to people working with computers at that time without any formal education in computer science.

3. Computer Science arrives to the university: decade of 1970

The *Instituto de Informática* started its regular courses in 1970 according the above commented curriculum. It created a delegation in Donostia in 1971 and in 1972 the *Universitat Autònoma de Barcelona* created a Department of Informatics in its Faculty of Sciences. This Faculty was obliged to follow the same curriculum of the *Instituto de Informática*. The team that started to teach Computer Science in this University (I belonged to it) was a mixture of good professionals and people having followed some university computer courses, mainly in France (Paris and Grenoble); they kept the titles of the official curriculum but they tried to transform the contents into a more reasonable structure according to the university spirit.

In 1974, the Spanish Ministry of Education considered that Informatics had to be included in the regular university structure. A commission was created to study how to pass the *Instituto de Informática* and its satellites to the university. Several universities fought in this commission to get computer studies. Finally by the end of 1975 it was decided that three Faculties of Informatics had to be created: Barcelona (in the *Universitat Politècnica de Catalunya*), Donostia (in the *Euskal Herriko Unibertsitatea*) and Madrid (in the *Universidad Politécnica de Madrid*), and that the previous institutions giving informatics studies had to stop to teach informatics [6]. This was true in Madrid and Donostia because the *Instituto de Informática* and its delegation were incorporated in the corresponding universities and their denomination changed. In Barcelona the situation was more complicated because it was necessary to passing studies from one university to another (unbelievable in Spain at that time). Finally, both universities kept their studies. The new Faculties started to work in October 1977 with a five year curriculum that, for the first time in Spain, was different for each university. In addition, in the Faculty of Barcelona the classical curriculum structure of a set of courses per academic year was broken and the curriculum was organized by courses with their corresponding pre-requisites in such a way that the student was able to organize his/her own curriculum choosing courses among those offered by the Faculty but respecting some compulsory courses [7]. A draft version of this curricula can be found in [13]. In all cases curricula were planned for five years of studies. Curricula of the Madrid and Donostia Faculties followed the traditional structure. In all cases, but especially in the Faculty of Barcelona, curricula were inspired by the ACM Computer Curriculum 1968 [1]. The students that successfully followed the studies in one of these universities obtained the title of *Licenciado en Informática* (Licensed in Informatics).

For its novelty at that moment, the structure of the Faculty of Barcelona and its curriculum follows. The Faculty was organized around 8 departments: Mathematics, Theoretical Computer Science, Computer Programming, Computer Architecture, Physical Systems, Automatic and Hybrid Systems, Statistics, and Information Systems.

Students arriving to the Faculty had a first year with the following courses:

- Computers and programming
- Algebra
- Mathematical Analysis I (Infinitesimal calculus)
- Representation techniques
- Physics

To get the first cycle of this License it was compulsory to succeed in the following courses:

- Mathematical analysis II
- Computer structure
- Information structure
- Programming technology
- Statistics
- Operating systems

Each course was assigned a number of credits (1 credit was 1 hour of course per week during an academic year) and to earn the first cycle a student should get courses for an amount of 75 credits and to earn the second cycle (*Licenciado en informática*) a student should get courses for an amount of 50 supplementary credits.

Each course had some pre-requisites, could be compulsory (C) or optional (O) and be valid for just the first cycle (F) or for both (B). A (C) beside some pre-requisite means that both courses can be followed in parallel.

Department of Mathematics

Course	Acronym	Credits	Pre-req.	Class	Validity
Algebra	AL	5	None	C	F
Mathematical analysis I	AM-1	5	None	C	F
Mathematical analysis II	AM-2	6	AN-1	C	F
Numerical calculus	CN	4	AL, AN-2, TR	O	F
Representation techniques	TR	3	None	C	F
Numerical analysis	AN	4	CN	O	B
Information and coding theory	TIC	4	AF, E	O	B

Department of Theoretical Computer Science

Course	Acronym	Credits	Pre-req.	Class	Validity
Finite automata	AF	6	AL, E	O	B
Computability theory	TC	4	AF	O	B
Language theory	TL	4	C, AF	O	B
Mathematical logic	LM	4	AL, CP	O	B
Artificial intelligence	AI	4	LM, TL, AD	O	B

Department of Computer Programming

Course	Acronym	Credits	Pre-req.	Class	Validity
Computers and programming	CP	7	None	C	F
Information structure	EI	4	CP	C	B
Programming languages	LP	4	AL, CP	O	B
Programming technology	TP	4	AL, CP	C	B
Compilers	C	4	EI, LP	O	B
Files and data bases	FBD	5	EI, LP	O	B

Department of Computer Architecture

Course	Acronym	Credits	Pre-req.	Class	Validity
Computer structure	EC	4	CP, AL	C	F
Operating systems	SO	4	EC, EI, TP	C	B
Computer architecture	AC	4	EC, AF	O	B
Design and evaluation of configurations	DAC	4	AC, SI	O	B
Communications and computer networks	CRC	4	SO, AC, SI	O	B
Operating systems design	DSO	4	SO, AC	O	B
Diagnostic and reliability	DF	4	AC, TIC	O	B

Department of Physical Systems

Course	Acronym	Credits	Pre-req.	Class	Validity
Physics	F	5	None	C	F
Electronics	EL	4	F, AN-1	O	F
Digital circuits	CD	4	EL, AF	O	B
Design of computers	DC	4	CD, AC, DAH	O	B
Peripheral equipments	EP	4	CD	O	B
Analogical and hybrid design	DAH	4	EL	O	B

Department of Statistics

Course	Acronym	Credits	Pre-req.	Class	Validity
Statistics	E	5	AL, AN-2	C	F
Simulation	SI	4	E	O	B
Data analysis	AD	3	E	O	B
Stochastic processes	PE	4	E	O	B
Optimization	O	5	AN-2, AL, E (c)	O	B
Optimization algorithms	AO	4	E, O	O	B
Operational research	OR	4	E, O	O	B

Department of Automatic and Hybrid Systems

Course	Acronym	Credits	Pre-req.	Class	Validity
Systems and signals	SS	4	AN-2, ES (c)	O	B
System dynamics	DS	4	SS	O	B
Optimal control and filtering	COF	4	DS, PE	O	B
Analogical and hybrid calculus	CAH	4	AN-2, LP, EL	O	B
Architecture and design of control systems	ADSM	4	SS, CAH	O	B
Real-time operating systems	SOTR	4	SO, SS	O	B

Department of Information Systems

Course	Acronym	Credits	Pre-req.	Class	Validity
Economy	ECO	3	None	O	F
Design and utilization of files and data bases	DUABD	3	EI, DT (c)	O	B
Technological design	TP	4	TP DUABD (c), SO (c)	O	B
Logical design of information and decision systems	DL	5	DT, DUABD, EO	O	B
Project methodology	MP	5	DL, TO	O	B
Organization structures	EO	3	ECO	O	B
Organization techniques	TO	3	EO	O	B
Organization administration	AO	4	EO	O	B
Computer centre management	GSI	2	DL, TO	O	B
Group dynamics	DG	2	TO, AO	O	B
Law	DE	2	AO	O	B

4. General Restructuring of University Studies: Decade of 1980s

Around 1980 a new three years study in Informatics was created and started in Madrid (*Universidad Politécnica de Madrid*) and Valencia (*Universitat Politècnica de València*). The students that successfully followed these studies obtained the title of *Diplomado en Informática* (Diplomate in Informatics). Some after the *Universidad de Las Palmas de Gran Canaria* and the *Univeristat de les Illes Balears* (Palma de Mallorca) created three year studies in Informatics. When these studies in Valencia, Las Palmas and Palma de Mallorca reached the third year, extensions to five years were implemented in Valencia, Las Palmas and Palma de Mallorca. These three years studies had two orientations or intensifications:

- Computer systems, mainly devoted to a vision of the computer under the user interface
- Business management applications

In the last years of this decade the Spanish Ministry of Education started a general reorganization of all university studies creating a catalogue of official titles (those delivered by the Ministry itself based on the studies done in some university) reorganizing the existing titles and creating new ones. To get official acceptance by the Ministry each one of these titles had to respect a set of contents established by the Ministry (main topics). To describe the relative importance of each of these topics a measure was invented: the credit equivalent to ten hours of teaching (including all kind of activities driven by the university teaching staff: theoretical classes, practical classes, etc.) received by the students. An academic year was estimated to have 30 weeks.

In the case of informatics three new titles were created and those existing till that moment disappeared:

- *Ingeniero en Informática* (Informatics Engineer): five years divided in two cycles and between 300 and 400 credits [8].
- *Ingeniero Técnico en Informática de Sistemas* (Technical Engineer in Informatics: Computer systems orientation): three years and between 180 and 225 credits [9].
- *Ingeniero Técnico en Informática de Gestión* (Technical Engineer in Informatics: Computer business management orientation): three years and between 180 and 225 credits [10].

The main contents of these new careers were:

Ingeniero en Informática

First cycle

Main topic and description	Credits
Statistics Descriptive statistics. Probabilities. Applied statistical methods.	6
Structure Data and Information Abstract data types. Data structures and manipulation Algorithms. Information structure: Files, Data bases.	12

Computer structure and technology Functional Units: Memory, Processor, Periphery, Machine and Assembly Languages, Functional schema. Electronics. Digital Systems. Peripheral devices.	15
Informatics physical fundamentals Electromagnetism. Solid state. Circuits.	6
Informatics mathematical fundamentals Algebra. Mathematical Analysis. Discrete Mathematics. Numerical Methods.	18
Programming Methodology and Technology Algorithms design. Algorithms analysis. Programming Languages. Programmes design: Modular decomposition and documentation. Programmes verification and testing techniques.	15
Operating Systems Operating systems organization, structure and services. Memory and processes management and administration. Input/output management. File systems.	6
Automata and Formal Languages Theory Sequential machines and finite automata. Turing machines. Recursive Functions. Formals grammars and Languages. Neuronal networks.	9

Second cycle

Main topic and description	Credits
Computer architecture and engineering Parallel architectures. Architectures oriented to applications and languages.	9
Software engineering Requirements analysis and definition. Software design, properties and maintenance. Configuration management. Planning and management of informatics projects. Applications analysis.	18
Artificial Intelligence and knowledge engineering Heuristics. Knowledge based systems. Learning. Perception.	9
Language Processors Compilers, translators and Interpreters. Compiling phases. Code optimization. Macroprocessors.	9
Networks Networks Architecture. Communications.	9
Informatics Systems Analysis methodology. Informatics systems configuration, design, management and evaluation. Informatics systems environments. Advanced technologies of information systems, data bases and operating systems. Projects of informatics systems.	15

Ingeniero Técnico en Informática de Sistemas

Main topic and description	Credits
Statistics Descriptive statistics. Probabilities. Applied statistical methods.	6
Structure Data and Information Abstract data types. Data structures and manipulation algorithms. Information structure: Files, data bases.	12
Computer structure and technology Functional units: Memory, processor, periphery, machine and assembly languages, Functional schema. Electronics. Digital systems. Peripheral devices.	15
Informatics physical fundamentals Electromagnetism. Solid state. Circuits.	6
Informatics mathematical fundamentals Algebra. Mathematical analysis. Discrete mathematics. Numerical methods.	18
Programming Methodology and Technology Algorithms design. Algorithms analysis. Programming languages. Programmes design: Modular decomposition and documentation. Programmes verification and testing techniques.	12
Networks Networks Architecture. Communications.	6

Operating Systems Operating systems organization, structure and services. Memory and processes management and administration. Input/output management. File systems.	6
Automata and Formal Language Theory Sequential machines and finite automata. Turing machines. Recursive functions. Formal grammars and languages. Neuronal networks.	9

Ingeniero Técnico en Informática de Gestión

Main topic and description	Credits
Statistics Descriptive statistics. Probabilities. Applied statistical methods.	9
Structure Data and Information Abstract data types. Data structures and manipulation algorithms. Information structure: Files, data bases.	12
Computer structure and technology Functional units: Memory, processor, periphery, machine and assembly languages, Functional schema. Electronics. Digital systems. Peripheral devices.	9
Business management software engineering Business management software design, properties and management. Planning and management of informatics projects. Analysis of management application.	12
Informatics mathematical fundamentals Algebra. Mathematical analysis. Discrete mathematics. Numerical methods.	18
Programming Methodology and Technology Algorithms design. Algorithms analysis. Programming languages. Programmes design: Modular decomposition and documentation. Programmes verification and testing techniques.	15
Operating Systems Operating systems organization, structure and services. Memory and processes management and administration. Input/output management. File systems.	6
Organization techniques and business management Economic system and business. Administration and accounting techniques.	12

Also it was stated that the students having earned one of these three years degrees were allowed to follow the second cycle of *Ingeniero en Informática*.

5. Set Up of the New Careers: Decade of 1990s

In the early years of this decade all universities giving the old degrees in informatics adapted their curriculum to the new characteristics. This adaptation took different solutions:

- Universities that delivered the three degrees separately: the five years degree in a faculty or school and the three year degree in a different school.
- Universities that delivered the three degrees in the same faculty or school with a complete implementation of the three degrees.
- Universities that delivered the three degrees in the same faculty or school but without the implementation of the first cycle of *Ingeniero en Informática* and using both three years degrees as the first cycle.
- Universities that had just the five years degree.
- Universities that had one or both three years degrees.

However, soon several problems appeared:

- The fact that three different first cycles gave access to the second cycle introduced difficulties in different topics like networks, computer architecture and software engineering. The reasons were that sometimes the same main topic with the same descriptors had assigned a different number of credits or that the student coming from some first cycle had previous knowledge of some topic not known for the students coming from other first cycles.
- The low number of credits assigned to operating systems obliged most universities to create supplementary courses in this topic.
- The growing importance of networking. It was remarked that it was possible that an *Ingeniero Técnico en Informática de Gestión* could earn his/her title with no knowledge of networking.
- The inconvenience of having Automata theory as a compulsory topic in the first cycle of *Ingeniero en Informática* (too theoretical for beginners) and in *Ingeniero Técnico en Informática de Sistemas* (too theoretical for the applied orientation of the three years studies).

During this period the number of faculties and schools delivering these degrees was continuously increasing (and currently there are approximately 80 in Spain). This fact and the need for exchanging information about experiences and discussing the difficulties in the implementation of their curricula provoked the need of discussion meetings with the participation of all faculties and schools teaching informatics careers. These annual meetings started in 1995. However, as the number of schools and faculties was continuously increasing, in 1998 it was decided to set up a minimal organization with a president and a secretary and a title: *Conferencia de Decanos y Directores de Centros Universitarios de Informática*, CODDI (Conference of Deans and Directors of Informatics University Centres). The first task assigned just after the appointment of a president was the review of the main topics of the informatics careers in order to correct the detected inconveniences. In 1999 this task was completed and the result was [4]:

Ingeniero en Informática

First cycle

Main topic and description	Credits
Algebra and discrete mathematics Basic algebraic structures. Lineal algebra. Combinatory. Discrete structures: graphs, trees. Logic. Coding. Numerical applications.	12
Mathematical analysis Successions and series. Integration. Differential equations. Numerical applications.	6
Data bases Data models. Data base management systems.	6
Statistics Probabilities. Applied statistical methods. Statistical inference.	6
Computer structure Functional units: memory, processor, input/output. Machine and assembly languages. Running schema. Microprogramming.	12
Informatics physical fundamentals Electromagnetism. Electronics. Circuits	6
Software engineering fundamentals Software systems analysis and design. Software properties and maintenance. User interfaces.	6

Programming and data structure Algorithms design and analysis. Programming paradigms and languages. Basic techniques of programmes design, verification and testing. Object oriented programming. Abstract data types. Data structures and manipulation algorithms.	21
Computer networks Communication elements and systems. Hierarchical structure of networks. Usual types of networks: local area networks and wide area networks. Network interconnection. Security.	6
Operating systems Operating systems organization, structure and service. Memory, processes and resources management and administration. Input/output management. File systems.	9
Computer technology Electronic components and systems of computers. Digital Systems. Microprocessors. Peripherals structure and functioning.	6

Second cycle

Main topic and description	Credits
Computer architecture Speed increasing techniques. Parallel architectures.	9
Automata theory, formal languages and language processors Sequential machines and finite automata. Turing machines. Complexity theory. Recursive functions. Formal grammars and languages. Compilers. Translators and interpreters. Compilation phases. Macroprocessors.	15
Software Engineering Requirements analysis and definition. Software properties and maintenance. Software quality assurance. Software projects planning and management. Methodologies. Human-machine interfaces.	15
Artificial intelligence Heuristics. Knowledge representation techniques. Knowledge based systems. Perception.	6
Networks and distributed systems Network configuration, administration and management. Interconnection. High performance networks. Quality of service. Security. Information compressing. Distributed systems.	9
Informatics systems Analysis methodology. Informatics systems configuration, design, management and evaluation. Informatics systems environments. Advanced technologies of information systems, data bases and operating systems. Projects of informatics systems. Audit. Security.	12

Ingeniero Técnico en Informática de Sistemas

Main topic and description	Credits
Algebra and discrete mathematics Basic algebraic structures. Lineal algebra. Combinatory. Discrete structures: graphs, trees. Logic. Coding. Numerical applications.	12
Mathematical analysis Successions and series. Integration. Differential equations. Numerical applications.	6
Data bases Data models. Data base management systems.	6
Statistics Probabilities. Applied statistical methods. Statistical inference.	6
Computer structure Functional units: memory, processor, input/output. Machine and assembly languages. Running schema. Microprogramming.	12
Informatics physical fundamentals Electromagnetism. Electronics. Circuits	6
Software engineering fundamentals Software systems analysis and design. Software properties and maintenance. User interfaces.	6

Programming and data structure Algorithms design and analysis. Programming paradigms and languages. Basic techniques of programmes design, verification and testing. Object oriented programming. Abstract data types. Data structures and manipulation algorithms.	21
Computer networks Communication elements and systems. Hierarchical structure of networks. Usual types of networks: local area networks and wide area networks. Network interconnection. Security.	6
Operating systems Operating systems organization, structure and service. Memory, processes and resources management and administration. Input/output management. File systems.	9
Computer technology Electronic components and systems of computers. Digital Systems. Microprocessors. Peripherals structure and functioning.	6
Informatics systems Management, planning and development of computer systems projects.	6

Ingeniero Técnico en Informática de Gestión

Main topic and description	Credits
Algebra and discrete mathematics Basic algebraic structures. Lineal algebra. Combinatory. Discrete structures: graphs, trees. Logic. Coding. Numerical applications.	12
Mathematical analysis Successions and series. Integration. Differential equations. Numerical applications.	6
Data bases Data models. Data base management systems.	6
Statistics Probabilities. Applied statistical methods. Statistical inference.	6
Computer structure Functional units: memory, processor, input/output. Machine and assembly languages. Running schema. Microprogramming.	12
Software engineering fundamentals Software systems analysis and design. Software properties and maintenance. User interfaces.	6
Programming and data structure Algorithms design and analysis. Programming paradigms and languages. Basic techniques of programmes design, verification and testing. Object oriented programming. Abstract data types. Data structures and manipulation algorithms.	21
Computer networks Communication elements and systems. Hierarchical structure of networks. Usual types of networks: local area networks and wide area networks. Network interconnection. Security.	6
Operating systems Operating systems organization, structure and service. Memory, processes and resources management and administration. Input/output management. File systems.	9
Informatics systems Management, planning and development of computer business application projects.	6
Business structure and functions Business as a system. Management and administration techniques. Organization structures.	6
Information systems Evaluation and management of information systems development. Strategic planning of information technologies and systems de. Applications.	6

This new definition of the main topics for the three degrees corrected the main defaults of the previous one:

- The same topic had the same description and the same number of credits.
- Networking was compulsory in the three first cycles.
- Two theoretical topics disappeared from the first cycles.

- Mathematics was split between Algebra and Analysis.
- Operating systems had a greater number of compulsory credits.

CODDI submitted this proposal to the Ministry of Education. However it was not accepted because its acceptance would have allowed other careers also to request the modification of their compulsory main topics. And this would have introduced a high degree of discussion between universities and between these and the Ministry. Nevertheless it was accepted as guidelines for the analysis and acceptation of future curricula submitted to the Ministry by the universities.

6. Towards the European Higher Education Space (EHES): decade of 2000s

Coincidental with the change of millennium, the European Union decided to ask the member states to reorganize their university systems in such a way that a convergence was reached around 2010 in two main aspects:

- University studies should be organized in three levels: bachelor, master and doctorate.
- University studies should define for each course the effort required of the student. The European Credit Transfer System (ECTS), equivalent to approximately 25 to 30 hours of work for the student including all his/her activities (theoretical courses, practical courses, seminars, personal study, etc.).

This convergence was named as the Bologna process because the agreement of all the member states was reached in a meeting held in the city where the first European university was created.

In 2001 CODDI started to work on how to adapt informatics studies to this convergence process. Initially a set of considerations showing mismatches in either the university studies structure or in the consideration by society of the degrees delivered by the university [2]. These considerations were:

- It was observed that neither the market nor the universities had succeeded to clearly discern the professional and educational differences between the *Ingenierías Técnicas en Informática* and the *Ingeniería en Informática* due to the constant evolution of informatics and professional changes.
- The difficulties found at the second cycle of the *Ingeniería en Informática* due to coexistence of students coming from three different first cycles.
- The fact that the *Ingenieros Técnicos* did not have professional acknowledgement at European level as university graduates.
- The difficulty for defining competencies and responsibilities of the informatics professionals.
- The great number of new activities with a fuzzy limit with other engineering branches (telecommunication engineers, industrial engineers, etc.).
- The consequences of the effort done to offer a higher non-university education, public as well as private, obliged to reconsider the structure, contents and level of informatics university studies.

The main conclusions of these discussions were [3]:

- An initial premise said that the market would experience a strong growth of demand in a near future. The strategic presence of informatics suggested the need of a set of solutions considering all education levels (primary education, secondary education, vocational education) and not only the university level.
- In this sense deep consideration about the University planning had to be done to take into account the geographical distribution and the resources needed to attain the planned objectives.
- The university structure would have to be organized in two cycles: *Grado* (degree) and Master.
- There had to be just a unique title of *Grado* whose name would be *Ingeniería en Informática* (Informatics Engineering).
- The title of *Ingeniero en Informática* would furnish full professional competencies for the exercise of the profession.
- The education furnished at the *Grado* level would be general in the informatics domain.
- The *Grado* studies would have 240 ECTS credits organized en 4 years.
- Among the fundamental educational contents of the *Grado*, there had to be an End of Studies Project, that would integrate the knowledge acquired by the student during his/her studies and that would make an approximation to real professional cases as well as to transversal contents that would put in evidence his/her abilities for the exercise of engineering activities.
- The common educational contents of the *Grado* would represent about 60% of the total study load, including the End of Studies Project, leaving 40% for topics to be freely decided by each university.
- Among the courses to be freely decided by the universities, it was recommended to have a large enough offer of courses oriented to give the students a solid knowledge of current informatics technologies as well as application domains.
- The Master would have as objective the professional specialization of the *Ingeniero en Informática* or his/her preparation for the research.
- The number of Master degrees would be large enough to cover the demand of specialized professionals at every moment.
- Master studies would have between 60 and 120 ECTS credits, depending on the previous degree earned and would include some effort allocated to a Master Thesis
- The Master degree would allow access to the preparation of a doctoral thesis to obtain the Doctor degree.

The structure of the studies is represented in the following table.

Contents			**Min.**	**Max**	
Common educational contents	60%	Scientific base	10%	15%	Informatics mathematical fundamentals. Informatics physical fundamentals.
		Informatics engineering specific contents	35%	40%	Programming. Software engineering. Information systems engineering. Intelligent systems engineering. Operating systems. Distributed systems and networking. Computer engineering.
		General contents of engineering	5%	10%	Business management. Ethical, legal and professional aspects. Professional abilities.
		End of studies project	6%	6%	
Contents freely decided by the university	40%				
Total effort		240 ECTS credits			

The students that earn the *Grado en Ingeniería en Informática* would be characterized by the following:

- To be prepared to exercise his/her profession, having a clear knowledge of the human, economic, social, legal and ethical dimensions.
- To be prepared to assume responsible tasks in any kind of organization along his/her professional life, in technical as well as in managerial positions, and to contribute in information and knowledge management.
- To have the required abilities in the professional practice of engineering: to be able to manage projects, to communicate in a clear and effective way, to work in a multidisciplinary team as well as to manage it, to adapt himself/herself to the changes and to autonomously learn along with his/her life.
- To be prepared to learn and to use in an effective way techniques and tools that could appear in the future. This versatility had to be especially valuable in organizations in which permanent innovation was needed.
- To be able to specify, design, build, verify, audit, evaluate and maintain informatics systems giving answers to user needs.
- To have the basic education to be able to continue his/her studies of Master and Doctorate in Spain or elsewhere[1].

[1] Up to this point, with very small differences this article is a copy of the paper presented at the conference on History of Computer and Education, HCE3, in the frame of the IFIP World Computer Congress WCC 2008 [14].

7. Implementation and follow up of the EHES: decade of 2010

7.1 Implementation

Several changes in the Spanish Ministry of Education delayed the implementation of the EHES. Finally in 2007 the framework for the implementation of the EHES was set up [11]. Some points were clear but the framework was not yet complete:

- There would not be a catalogue of official titles; each university had to propose its own titles that would be validated by an independent agency (*Agencia Nacional de Evaluación de la Calidad del Sistema Universitario* – ANECA, National Agency for the Evaluation of the Quality of the University System) that would evaluate the appropriateness of the proposed title (specially avoiding confusion to society), the quality of the proposal and the existence of a sufficient amount of human and material resources allocated to the correct implementation.
- The *Grado*, in our case of *Ingeniero en Informática*, would have 240 ECTS that would include the end of studies project.
- The Master degree would have 60 or 120 ECTS depending on the coherence between the grade earned and the intended Master.

From this information it was easy to see that the proposal of the CODDI, several years before the decisions of the Ministry, was fully in line with the framework in which the universities would work in the near future.

Early in 2008 five commissions were set up to analyse the new curricula on Science, Engineering, Health, Law and Economics, and Letters and Humanities. Informatics was included in the engineering domain.

In order to understand the environment, it is necessary to know that all classical engineering studies (civil engineers, mining engineers, naval engineers, industrial engineers, agronomical engineers, forest engineers, aeronautical engineers and telecommunication engineers) have exclusive professional capabilities and are differentiated by branch and level (3 years or 5 years of studies) and associated to the academic diploma. This organization causes serious conflicts of interests in which are involved the corresponding professional associations. The informatics engineers have no defined professional capabilities and their professional space is frequently invaded by other engineering branches, mainly the industrial and telecommunication engineers.

Traditional engineering associations were against the decision of the government of associating professional capabilities to the *Grado* diploma when there were different capabilities for diplomas of 3 and 5 years. Before solving this fight, the verification process started in March 2008. This process was theoretically very well-conceived but looking more to how to teach than what should be taught. However, there were terms not clearly defined, related between them and critical for the correctness of this process, like: objectives, competencies, modules, matters, courses, contents, learning outcomes, etc.

Points to verify were:

- Title description
- Justification
    - Academic, scientific or professional interest
    - External references of the title
    - Consultation procedures
- Objectives
    - General and specific competencies
- Students access and admission
    - Information systems prior to registration and reception procedures and guidance for students newly admitted
    - Conditions or special admission tests
    - Support and guidance to students once enrolled
    - ECTS recognition and transfer
    - Course of adaptation
- Teaching planning
    - Knowledge structure
    - Student mobility
    - Description of modules, matters and courses
- Academic staff
    - Teaching staff and other human resources needed and available
    - Adequacy of faculty staff to support the curriculum
- Material resources and services
    - Available material resources
    - Planned material resources
- Planned results
    - Estimation of indicators
    - How to assess progress and learning outcomes
- Quality assurance system
    - Responsible for system quality assurance of curriculum
    - Procedures for assessing and improving the quality of teaching and faculty staff
    - Procedures to ensure the quality of internships and mobility programs
    - Procedures for analyzing the employment of graduates and satisfaction with the obtained training
    - Procedures for the analysis of the satisfaction of the different stakeholders and attention to suggestions and complaints. Criteria for the extinction of the title
- Implementation schedule
    - Implementation chronogram
    - Adaptation of the existing curricula students
    - Careers to be extinct

The verification commissions started to work with a formal description of its work but with an important lack of definitions (as explained before) and fundamental and logistic problems. Among the last ones an important difficulty was the lack of a good management system for the proposals. Due to the lack a good definition of its task, commission members used their better knowledge to the proposal analyses. Two points were taken especially into account:

- The name of the title should represent the delivered contents.
- The title description should not induce into error the future students reading the document with the intention of following these studies.

However, as classical engineering studies had associated professional capabilities supported by the corresponding professional associations, the need soon appeared to define the objectives and competencies of these studies. To solve this problem the Spanish Ministry of Education published in February 2009 these characteristics for all classical engineering studies. Nevertheless these definitions were not an example of well doing because:

- The objectives were defined in terms of competencies.
- The competencies were defined in terms of teaching contents.

This decision was against the previous definition in which the *Grado* gave the professional capabilities and the Master gave the specialization. With this decision the *Grado* gave the professional capabilities of the 3-years engineers in its concrete specialties and after obtaining the Master they got all the professional capabilities of 5-years engineers. This approach has the above mentioned inconvenience of passing from a specialized knowledge to a general one.

In the case of Informatics Engineering and some other newly created they had no professional capabilities. This fact represented to place them in a lower level than the classical engineers and the CODDI fight to have at least a definition of its studies similar to the other engineering studies even if they had not professional capabilities. This was obtained in August 2009 when the Ministry of Education published the definition of objectives and competencies for the *Grado* and Master in Informatics Engineering [12] with a better conception avoiding the definition of objectives in terms of competencies and the competencies in terms of teaching contents. This definition included the five specific technologies defined in the ACM/IEEE-CS Computing Curricula [14] in a similar way to the other classical engineers all of them had several specialties:

- Computer Engineering
- Software Engineering
- Computing
- Information Systems
- Information Technology

These specific technologies are different in their competencies but have the same objectives. The objectives are:

1. Ability to design, write, organize, plan, develop and sign projects in informatics engineering whose goal, according the knowledge acquired in agreement with the competencies, is the conception, development or exploitation of informatics systems, services and applications.
2. Ability to lead informatics activities projects in the field of computing according to the knowledge acquired in agreement with the competencies.

3. Ability to design, develop, evaluate and ensure accessibility, ergonomics, usability and safety of the systems, services and applications, as well as the management of information.
4. Ability to define, evaluate and select hardware and software platforms for the development and implementation of systems, services and applications, according to the knowledge acquired in agreement with the competencies.
5. Ability to design, develop and maintain computer systems, services and applications using the methods of software engineering as a tool for quality assurance according to the knowledge acquired in agreement with the competencies.
6. Ability to design and develop systems or centralized or distributed architectures integrating hardware, software and networks according to the knowledge acquired in agreement with the competencies.
7. Ability to recognize, understand and implement the necessary legislation during the development of the profession *Ingeniero Técnico en Informática* and use specifications, regulations and mandatory standards.
8. Knowledge of basic materials and technologies that enable learning and development of new methods and technologies as well as to equip them with great versatility to adapt to new situations.
9. Ability to solve problems with initiative, decision making, autonomy and creativity. Ability to communicate and transmit the knowledges, skills and abilities of the profession of *Ingeniero Técnico en Informática*.
10. Knowledge to perform measurements, calculations, assessments, appraisals, surveys, studies, reports, scheduling and similar computer works, according to the knowledge acquired in agreement with the competencies.
11. Ability to analyse and assess the social and environmental impact of technical solutions, understanding the ethical and professional responsibility of the activity of *Ingeniero Técnico en Informática*.
12. Knowledge and application of basic economic and human resource management, organization and planning of projects as well as legislation, regulation and standardization in the field of ITC projects, according to the knowledge acquired in agreement with the competencies.

The competencies structure is the following:

- Module of basic knowledge: 60 ECTS
  - Ability to solve mathematical problems that may arise in engineering. Ability to apply knowledge of: linear algebra, differential and integral calculus, numerical methods, numerical algorithms, statistics and optimization.
  - Understanding and mastery of basic concepts of fields and waves and electromagnetism, theory of electrical circuits, electronic circuits, semiconductor physical principle and logic families, electronic and photonic devices and their application to solving engineering problems.
  - Ability to understand and master the basic concepts of discrete mathematics, logics, algorithmics and computational complexity, and their application to solving engineering problems.

- Basic knowledge of use and programming of computers, operating systems, databases and computer programs with applications in engineering.
- Knowledge of the structure, organization, operation and interconnection of computer systems, the fundamentals of programming and its application to solving engineering problems.
- Adequate knowledge of the company concept, institutional and legal framework of the company. Business organization and management.

- Module common to the informatics branch: 60 ECTS
  - Ability to solve mathematical problems that may arise in engineering. Ability to apply knowledge of: linear algebra, differential and integral calculus, numerical methods, numerical algorithms, statistics and optimization.
  - Ability to design, develop, select and evaluate computer applications and systems, ensuring their reliability, safety and quality, according to ethical principles and the current laws and regulations.
  - Ability to plan, design, deploy and manage computer projects, services and systems at all domains, leading its implementation and continuous improvement and assessing their economic and social impact.
  - Ability to understand the importance of negotiation, effective work habits, leadership and communication skills in all software development environments.
  - Ability to develop the technical specifications of a computer facility that meets the current standards and regulations.
  - Knowledge management and maintenance of computer systems, services and applications.
  - Knowledge and application of basic algorithmic procedures of information technologies to design solutions to problems by analysing the appropriateness and complexity of the proposed algorithms.
  - Knowledge, design and efficient use the data types and structures best suited to solving a problem.
  - Ability to analyse, design, build and maintain applications in a robust, secure and efficient way, by choosing the most appropriate paradigm and programming languages.
  - Ability to learn, understand and evaluate the computer’s structure and architecture and the basic components that comprise them.
  - Knowledge of operating systems characteristics, functionality and structure and design and implement applications based on their services.
  - Knowledge and application of distributed systems, computer networks and Internet characteristics, functionality and structure, and design and implement applications based on them.
  - Knowledge and application of databases characteristics, functionality and structure that allow their proper use, and design and analyze and implement applications based on them.

    - Knowledge and application of tools for storage, processing and access to information systems, including those web-based.
    - Knowledge and application of fundamental principles and basic techniques of parallel, concurrent, distributed and real-time programming.
    - Knowledge and application of fundamental principles and basic techniques of intelligent systems and their practical application.
    - Knowledge and application of principles, methodologies and life cycles of software engineering.
    - Ability to design and evaluate human computer interfaces to ensure accessibility and usability of computer systems, services and applications.
    - Knowledge of the computer domain rules and regulations at national, European and international levels.
- Specific technology module: software engineering, 48 ECTS
    - Ability to develop, maintain and evaluate software systems and services that satisfy all user requirements and behave reliably and efficiently, be affordable to develop and maintain and meet quality standards, applying the theories, principles, methods and practices of Software Engineering.
    - Ability to assess client needs and specify the software requirements to meet these needs, reconciling conflicting objectives by finding acceptable compromises within limitations imposed by cost, time, and the existence of systems already developed and own organizations.
    - Ability to solve integration problems in terms of strategies, standards and available technologies.
    - Ability to identify and analyse problems and design, develop, implement, verify and document software solutions based on adequate knowledge of the current theories, models and techniques.
    - Ability to identify, evaluate and manage potential associated risks that might arise.
    - Ability to design appropriate solutions in one or more application domains using methods of software engineering that integrate ethical, social, legal and economic aspects.
- Specific technology module: computer engineering, 48 ECTS
    - Ability to design and build digital systems, including computers, microprocessor based systems and communications systems.
    - Ability to develop specific processors and embedded systems as well as to develop and optimize software for such systems.
    - Ability to analyse and evaluate computer architectures, including parallel and distributed platforms as well as to develop and optimize software for them.
    - Ability to design and implement system and communications software.
    - Ability to analyse, evaluate and select hardware and software platforms better suited to support embedded and real-time applications.
    - Ability to understand, implement and manage the systems security and safety.

- Ability to analyse, evaluate, select and configure hardware platforms for the development and implementation of computer applications and services.
- Ability to design, deploy, and manage computer networks.

- Specific technology module: computing, 48 ECTS
  - Ability to have a thorough understanding of the fundamental principles and models of computing and to know how to apply these to interpret, select, assess, model, and create new concepts, theories, practices and technological developments related to computer science.
  - Ability to know the theoretical foundations of programming languages and the lexical, syntactic and semantic processing techniques associated to them, and to know how to apply them for the language creation, design and processing.
  - Ability to evaluate the computational complexity of a problem, to know algorithmic strategies that can lead to its resolution and recommend, develop and implement one that ensures the best performance in accordance with the requirements.
  - Ability to learn the fundamentals, paradigms and techniques of intelligent systems and to analyse, design and build systems, services and applications that use these techniques in any application scope.
  - Ability to acquire, obtain, formalize and represent human knowledge in a computable way for problem solving using a computer system in any application scope, particularly those related to computing, perception and action aspects in smart environments.
  - Ability to develop and evaluate interactive systems and of presentation of complex information and its application to solving design problems of human-computer interaction.
  - Ability to recognize and develop computational learning techniques and design and implement computer systems and applications that use them, including those dedicated to extracting information and knowledge from large volumes of data.
- Specific technology module: information systems, 48 ECTS
  - Ability to integrate solutions of Information and Communications Technology and business processes to meet the information needs of organizations, enabling them to achieve their goals effectively and efficiently, giving them competitive advantages.
  - Ability to determine requirements for information and communication systems of an organization in response to safety issues and compliance with regulations and legislation.
  - Ability to actively participate in the specification, design, implementation and maintenance of information and communication systems.
  - Ability to understand and apply the principles and practices of organizations so that they can act as liaison between technical and management communities within an organization and actively participate in the training of users.

    - Ability to understand and apply the principles of risk assessment and correctly apply them in the development and implementation of action plans.
    - Ability to understand and apply the principles and techniques of quality and technological innovation management in organizations.
- Specific technology module: information systems, 48 ECTS
    - Ability to understand the organization environment and its needs in the field of information and communications technology.
    - Ability to select, design, deploy, integrate, evaluate, build, manage, operate and maintain hardware, software and networks technology, within appropriate parameters of cost and quality.
    - Ability to use user-centred methodologies and organization development, evaluation and management of applications and systems based on information technologies to ensure accessibility, ergonomics and usability of systems.
    - Ability to select, design, deploy, integrate and manage network and communications infrastructure in an organization.
    - Ability to select, deploy, integrate and manage information systems that meet the needs of the organization, with identified cost and quality criteria.
    - Ability to design systems, applications and services based on network technologies, including Internet, web, e-commerce, multimedia, interactive services and mobile computing.
    - Ability to understand, implement and manage the security and safety of computer systems.
- End of *Grado* project: 12 ECTS
    - Original exercise to be performed individually and presented and defended to a university jury, consisting of a professional nature project in the area of the specific technologies in Informatics Engineering in which the skills acquired in the teachings are synthesized and integrated.

The rest, up to 240 ECTS, is at disposal of the University for strengthening the above mentioned topics, for stages in companies and for collateral activities (participation in representative activities, sports, volunteer work for the community, etc.).

With the existing degree of freedom for defining the title of the *Grado*, two alternatives were presented to the Universities:

- To propose a unique name with several technological specialties (or professions with professional capabilities, if any)
- To propose one or several names related to the technological specialties (or professions with professional capabilities) they want to develop.

In favour of independent titles for each specific technology of professions with recognized capabilities they are to be aligned with these professions and use socially recognized names. Instead, for a unique title with technological specialities there are the limitations imposed by the local governments concerning the number of careers they were ready to fund, to be aligned with the White Book recommendations and to find social recognition.

In order to avoid misunderstandings by future students the criteria followed by the verification commission was to accept a specific name if it was adapted to a specific technology or profession with capabilities (e.g. Software Engineer) and a generic name (e.g. Informatics Engineer) in the case of including several specific technologies.

7.2 Follow up

Two years after the implementation of the new studies, the ANECA has started a follow up procedure in order to have a look at how the Universities have implemented these new studies. The goal of this exercise is to assess the Universities about the points missing or not correctly implemented, especially with respect to the quality assurance procedures newly implemented by the university and to the new teaching orientation proposed by the Bologna agreement (instead of teaching the students, to learn them how to learn).

8. Conclusion

How will the future be? I think it will be necessary to wait ten years until we will be able to have an opinion about the success of this reform, mainly to evaluate how professors and students have changed their teaching and learning habits. This is, may be, the strongest challenge of this reform.

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