Agència
per a la Qualitat
del Sistema Universitari
de **Catalunya**

GUIDELINES FOR PREPARING A PROGRAMME SPECIFICATION

CHEMICAL ENGINEERING

Quality, the assurance of improvement.

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This document was prepared by the working party that consisted of:

Claudi Mans Teixidó, Coordinator, Faculty of Chemistry (UB); **Javier Tejero Salvador**, Faculty of Chemistry (UB); **Francesc Valero Barranco**, Escola Tècnica Superior d'Enginyeria (UAB); **Josep López Santín**, Escola Tècnica Superior d'Enginyeria (UAB); **Xavier Font Segura**, Escola Tècnica Superior d'Enginyeria, (formerly the Escola Universitària Politècnica de Medi Ambient) (UAB); **José Ignacio Iribarren Laco**, Escola Tècnica Superior d'Enginyeria Industrial (UPC); **Javier Cañavate Ávila**, Escola Universitària d'Enginyeria Tècnica Industrial de Terrassa (UPC); **Isabel Villaescusa Gil**, Escola Politècnica Superior (UdG); **Xavier Farriol Roigés**, Escola Tècnica Superior d'Enginyeria Química (URV); **Miquel Gassiot Matas**, Institut Químic de Sarrià (URL); and **Anna Prades Nebot** from AQU Catalunya, who was the Secretary.

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Via Laietana, 28, 5a planta
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Foreword

The process of adapting degrees to the European Higher Education Area (EHEA) is the perfect framework for a fundamental collective reconsideration of the approach, development and results that are sought in applying not just the new structure of degrees but also the new way of accounting for study time and the new mechanisms for assuring compliance with international standards. A key element within this context is the design stage of the study programme. With this in mind, the DISSENY programme was set up by AQU Catalunya to prepare specific guidelines for degree design involving all of the universities giving the study programmes. For various different reasons the DISSENY programme has focused on three disciplines, Medicine, Psychology and Chemical Engineering. Guidelines for the first two have already been published, and these guidelines for Chemical Engineering, which are the last in a programme dealing with specific subjects, are made up of three parts and cover the overall framework of the reform process for bringing degrees into line with the EHEA and the defining of the procedure for drawing up an appropriate study programme for each particular case.

On the basis of its experience with the DISSENY programme, AQU Catalunya has this year published general guidelines on submitting proposals for new degrees, the focus being on Masters degrees, which is the first type to conform to the new European format.

Designing degree courses with the participation of all the universities involved requires a group of capable people who are willing, unbiased and have good ideas and who, together with a good group coordinator, give impetus to the project. In the case of Chemical Engineering, we were fortunate to have a group that not only provided all the necessary qualities but was also extremely enthusiastic and mutually understanding. This is all the more commendable taking into account that all of the six Catalan universities that offer degrees in Chemical Engineering took part. Given these conditions, the resulting Guidelines are are of the very best quality and will be of great use for setting up new undergraduate study programmes in Chemical Engineering and a solid base for presenting Master programmes. On behalf of AQU Catalunya, I would like to thank the committee in general and particularly the coordinator for a job well done.

Gemma Rauret Dalmau
Director of AQU Catalunya

Abstract

The aim of the AQU Catalunya DISSENY programme is to prepare a series of guidelines for preparing programme specifications for certain undergraduate degree programmes within the framework of the European convergence process and in line with new Spanish and Catalan legislation, as well as competence-based criteria.

These Guidelines are the result of work carried out in the 2003 to 2005 academic years by a group set up by AQU Catalunya under the DISSENY programme to prepare a methodology for designing the study programme for the Bachelor degree in Chemical Engineering, in accordance with criteria recommended by AQU Catalunya. These criteria essentially involve preparing a programme based on the combination of competences required by employers —prior knowledge of which is therefore necessary—, the expertise of the faculty where the programme is being given, the strategic lines of the faculty and university, and the availability of space, equipment and teaching staff, together with the relevant directives that affect the programme.

This document consists of three parts:

- An initial reflection concerning the overall framework of the reform and process of European convergence, specific aspects of competence-based training (chapter 1) and specific aspects of training in chemical engineering (chapter 2).
- The design for a consultation process to identify the opinions of employers, teaching staff and recent graduates regarding the competences to be attained in the degree programme, followed by a critical consideration of the outcomes by a committee, and the preparing of a generic competence profile (chapter 3).
- The drawing up of a document that defines a procedure for preparing an appropriate study programme for a degree in a particular faculty and university (chapter 4).

The annex includes the questionnaire for the consultation process involving employers, teaching staff and recent graduates, the letter of introduction that presents the objectives of the project, and a description of the results of the consultation process.

The working group was made up of representatives from all the universities that currently offer degree programmes either in Chemical Engineering (long cycle) or Industrial Engineering, with the specialisation in Industrial Chemistry (short cycle), namely, UB, UAB, UPC, UdG, URV and URL.

Objectives

The Guidelines are aimed at senior academic staff, teaching staff and experts involved in designing the undergraduate degree programme for Chemical Engineering, as well as internal and external programme assessors. By extension, they may be useful for preparing other undergraduate and postgraduate degree programmes with similar characteristics to those of Chemical Engineering, i.e. programmes in the experimental sciences with an important applied science component, which are industry and services-orientated and with a comprehensive approach to problem solving.

The objectives of the Guidelines are to:

- Establish the basis for designing and implementing the chemical engineering degree programme that enable new elements to be combined with the way that these studies are currently implemented in Catalonia.
- Give guidelines for the internal and external evaluation of design and implementation of the programme.
- Serve as a model for the design of other analogous degree programmes.
- Contribute to promoting mechanisms for pedagogical renewal at university by suggesting new didactic methodologies, giving impetus to greater interaction between students and teaching staff, and emphasising the attainment of competences.

The decision was made to include certain prospects for the future in the contents. The fact that both industrial and higher engineers are currently sought after does not mean that aspects that are important in order to help graduates in Engineering be successful, such as the immediate applicability some of their knowledge, should now fall by the wayside. The document is thus a cross between the current programme, which is recognised and effective, and new lines for the future that include both content, methodology and organisation.

Details of the design of a study programme, which are worked out by the faculty, are not covered by this document. The programme specification will need to be contextualised for each faculty's degree in Chemical Engineering according to geographical factors, specialised knowledge and availability of resources and teaching tradition, amongst others.

In terms of the design of the programme specification, this document seeks to go beyond the types of present-day employment in chemical engineering to take in a broader perspective and cover the needs for training in sectors where the link with the profession is only just being developed, and within a global context, especially Europe.

1
Competence-based training

1.1. The European Higher Education Area

The European university system is undergoing a process in which the European Higher Education Area (EHEA) is being set up, in what is a move to create a situation that facilitates, at the EU level, the mobility of students and graduates, degree recognition, exchange, joint degrees between different participating States, as well as an increase in the competitiveness and attractiveness of European universities.

This process, known generically as the Bologna process, is the product of three processes carried out consecutively and, to a certain extent, independently of each other:

- An economic process, which seeks to make Europe one of the most dynamic centres in the world economy, based on research and knowledge, production with a high added value and the design of new products and materials. The nearest form to this in the past was the European Economic Community.
- A political process, which basically seeks wider integration between States to ensure greater stability, uphold —as far as possible— the social welfare state and defend democratic values, culture and civilisation. This takes its form as the European Union.
- An academic process, which seeks to invigorate European academic institutions through the greater mobility of students and academic staff, greater transparency between degrees at different institutions and states, and degree comparability for employment purposes. The form of this is the EHEA.

One of the most notable developments of the new system is the setting up of two degree levels, the undergraduate Bachelor degree and the postgraduate Master's degree, which students go on to study afterwards. Both of these are professionally orientated although each one is on a different level and involves different competences.

1.2. The framework of university training here and now

The Spanish university system is structured in such a way that different agencies are involved in planning, the defining of degree programmes, and decision-making processes regarding curricula and accreditation. It is the Spanish government that establishes recognised degrees, the overall framework, the basic directives and professional competences for each degree. Each Autonomous Community in Spain establishes the spectrum of degrees in the corresponding region, together with funding and other implementary aspects. Each university decides on a catalogue of subjects in accordance with its available assets, vocation, tradition and context, and each faculty and department design and follow the curriculum in accordance with the final programme specification.

It is the universities, and not the professional bodies or associations, that grant professional status. This principle, which is very specific to Spain and highly varied and modified in many professions, considerably limiting the professional bodies, makes the Spanish university system, and consequently the Catalan system as well, more interventionist compared to most European systems. In many places in Europe, it is the universities that, in the exercise of their capacity and freedom, define the degrees that they will offer, the contents and duration. Intervention by the public authorities has not been reduced in the process of bringing the Spanish system into line with the EHEA, and in fact the opposite has actually occurred.

1.3. Influences and determining factors

Use has been made here of the outline proposed in the *Marc general per al disseny, el seguiment i la revisió de plans d'estudis i programes* (AQU Catalunya, 2002, General framework for preparing, monitoring and reviewing study programmes and curricula). To summarise, there is a total of eight influences and determining factors to be taken into consideration when any programme specification is being prepared, and particularly a technical degree programme such as Chemical Engineering:

- **General social needs**, determined mainly by the Government:
    - The cultivation and spread of **knowledge**.
    - **Culturalisation and general training** in society.
    - The needs of **young people and recent graduates for specific employment-orientated training that results in employment**.

  - A general **regional policy** that is either geographically balanced or that develops certain zones, campuses, clusters, etc.

- The **needs of the labour market**, expressed mainly in terms of the demands of employers:
  - The economic structure of the **local context** that is in constant development, with new products, new processes and new technologies.
  - **Employers' expectations** of the characteristics of graduates, which in specific terms are aspects of higher level training, academic contents and, above all, competences and personal skills.
  - The existence of a labour market and different **concurrent and complementary degree programmes**.
  - The existence of a rapidly evolving, **globalised** technological and market economy, which generates high levels of mobility and frequent changes of company, sector and job throughout the course of one's life.
  - The increasing effect of **self-employment** and **entrepreneurship**.
- The **characteristics of the student** undergoing training:
  - **Social and academic background** and **previous training**.
  - The **abilities and skills required** for a degree programme.
  - **Limitations** of understanding due to lack of previous training, experience or knowledge, which condition the contents offered at each stage of the programme.
  - **Time availability** and the ability to plan ahead, which need to be sufficient for the demands of the training, according to the level.
- The **student's expectations and needs**, which are apparent in different aspects:
  - The need for **intellectual satisfaction**, in terms of both the subject content and the methodology used.
  - The possibility of **flexible time planning** adapted to the student's particular conditions.

    - The possibility of studies also satisfying students' expectations regarding **personal relationships and exchange**, facilitated by campus-based studies and the possibilities of exchange with foreign universities, relations with private enterprise, etc.
    - Sufficient **expectations of employment**, supported by appropriate services such as a careers office with job vacancies, work experience in private enterprise and career/job fairs.
- **The university policy of different administrations**. Policies with regard to thematic content, regional considerations, gender, etc. are determined by the political options of governments. These policies are determining factors when programme specifications are set for degrees, and for the faculties involved.
- The **internal potentialities** of the faculties and departments involved, in different facets:
    - The availability of appropriate space, facilities and teaching staff.
    - Proven experience in and tradition of the programme or other similar programmes.
    - Free-flowing contacts and solid relations with the scientific, technology and professional environment involved.
- **Professionals** involved in the programme:
    - Professional bodies and associations may influence and condition the specifications of the respective programme and degrees, as well as those of the environment, to maintain the existing *status quo* or modify it as a result of corporate motives.
    - Concurrence and competitiveness with other programmes within the same professional context, which generates tensions.
    - The judicialisation of many professional actions.
- The **European**, **state and regional regulations**. The different stakeholders must fulfil their role and exert their capacity of influence and conviction in the period when guidelines are being set.

1.4. Competence training

Competence is the skill acquired from adequately carrying out a task, duty or role. It is made up of two distinct components in that it is associated with specific work in a particular context and it incorporates different types of knowledge, skills and attitudes.

In a wider sense, competences are the general and subject specific knowledge, skills and motivation that make up the prerequisites for effective action in a wide variety of contexts that higher degree holders must deal with, and formulated in such a way that they are equivalent in terms of significance in all such contexts. Competence should not be confused with features of personality, which are an individual's more stable characteristics. Distinction also needs to be made between competences in a particular context and professional competences formulated in terms of prerogatives and legal capacity to carry out certain activities resulting from the possession of a particular degree qualification and/or membership to a certain professional body or association.

Transferable competences, for which there is currently considerable interest, are one way of solving a long-standing problem, namely, of knowing know what one learns at school is useful for. The concept of *competences* is a fairly new term, however, and is characterised in general by the confusion in use of terms (key competences, nuclear competences, skills, abilities, attitudes, etc.) and the lack of a theoretical framework for different studies.

The Tuning project (González and Wagenaar, 2003) is one of the most influential projects on the European scale dealing with the debate on competences in higher education. The objective of the initial stage of the project (2001-2002) was to define the contents and professional specifications for seven degree programmes of European standing and, through the identification of both specific and general or transversal competences, develop a methodology for understanding the curricula and their comparability between different states. The Tuning project report (2003) pointed to three main factors that underpin the interest in developing competences in educational programmes:

- The need to improve employability in the new knowledge society, due to factors such as the rapid obsolescence of knowledge and the need for life-long learning.
- The setting up of the EHEA, with the need to establish common benchmarks for degree programmes (the Dublin descriptors for Bachelors and Masters).

- The existence of a new educational paradigm that focuses on student learning and puts more emphasis on outcomes and the objectives of the programme.

The key characteristics of competences are:

- They identify the ability to successfully carry out a task or role in both habitual and new contexts.
- They incorporate or combine knowledge, abilities and attitudes.
- They can be acquired through *learning by doing* and they evolve as they are developed: from novice or beginner to expert.
- Unlike knowledge, abilities or attitudes, competences cannot be evaluated independently. They are always evaluated in a certain context, which raises doubts about their transferability.

Many classifications have been published on the competences of the university graduate, all of which vary according to the lists proposed, the terms used to describe certain competences and the ways used to structure them. The Tuning project is one of the most frequently used classifications and because of its link with the entire process of implementing the EHEA, it is worthwhile for it to be reproduced here. The objective of the Tuning project is to open a debate on the nature and importance of both general and subject specific competences in relation to the contents of degree programmes. From an initial list of 85 abilities and competences in the project, 30 competences were defined that first cycle students should combine in general. These competences were divided into three groups according to whether they are instrumental, interpersonal or systematic.

Instrumental

- Capacity for analysis and synthesis
- Capacity for organisation and planning
- Basic general knowledge
- Key basic knowledge of the profession
- Oral and written communication in the mother tongue
- Elementary computer competences
- Information management skills (extracting and analysing information from different sources)

- Problem-solving
- Decision-making

Interpersonal

- Skills of criticism and self-criticism
- Teamwork
- Interpersonal skills
- Ability to work in an interdisciplinary team
- Ability to communicate with experts in other fields
- Appreciation of diversity and multiculturality
- Ability to work in an international context
- Commitment to ethics

Systematic

- Capacity to apply knowledge in practice
- Research skills
- Capacity to learn
- Ability to adapt to new situations
- Ability to generate new ideas (creativity)
- Leadership
- Understanding of cultures and customs of other countries
- Ability to work on one's own
- Project management and design
- Initiative and entrepreneurship
- Concern about quality
- The will to be successful

Certain weak points are evident in the classification, such as various repetitions in different categories.

An examination of the different lists and classifications of competences reveals the following points of coincidence:

- The majority of competences that refer to higher education distinguish between subject specific competences and transversal or generic competences.
- Several generic competences are repeated insistently: critical thinking, problem solving (cognitive skills), team work, communication (interpersonal skills), initiative, responsibility, ethics, life-long learning (personal skills) and "things that are very useful" such as languages, computer skills, skills in searching for documentation, etc.

Different levels of intensification can be identified for each competence. For example, for preparing a Communication course, the term "oral communication" would probably be too broad a category (mention should be made of intonation, non-verbal communication, public speaking, etc.), whereas the term "verbal communication" as a generic competence of a programme, which implies the need to programme experiences throughout the student's studies where he/she would need to have recourse of the competence, is perfectly valid.

Preparing a programme in terms of competences is an approach that implies significant changes in the educational institution, teaching staff and students:

- Much more emphasis is put on active ways of learning, such as problem-solving, case analysis, behaviour simulation, experiments in real-life situations, etc.
- It requires an important change in the evaluation paradigm: the student is asked to construct the answer and it also requires test runs to be carried out and products, projects, algorithms, protocols, reports, judgements, etc. to be prepared.
- It requires an effort of coordination and overall planning.

There is the need to define a structured list of competences that is coherent and consensus-based, which establishes a desirable programme specification, which serves as the basis on which contents and teaching methodologies can then be considered. Sections 3 and 4 of these Guidelines go into these two aspects.

1.5. The generic process of designing a study programme

The generic proposal made by AQU Catalunya in the above-mentioned publication, *Marc general per al disseny, el seguiment i la revisió de plans d'estudis i programes* (AQU Catalunya, 2002), is the basis of these Guidelines, and only the most important features are given here. The process of preparing a study programme essentially consists of four points, which need to be developed successively:

- The analysis of internal and external contexts: need and viability.
- Processes and their agents.
- The structural elements of the study programme.
- Operational planning of the study programme.

A two-fold **analysis of the internal and external contexts** is made in these Guidelines. Chapter 2 goes into the perspective and objectives of training in Chemical Engineering today, taking into account not only the authors' opinions and the related bibliography but also the framework of Spanish degree programmes into which this programme will need to be incorporated. As the Guidelines are based on a competence-based design for a study programme, a detailed analysis is made in chapter 3 of the competences that employers, teachers and recent graduates define as desirable competences for the graduate in Chemical Engineering.

Details of the role of **processes and their agents** are given in chapter 4, which has three sections on the sequence of different stages to be carried out by a faculty in preparing and introducing the study programme, and for evaluating how it is implemented and run.

The **structural elements of the study programme** derive in part from Spanish directives and in part from the vision and objectives defined by the university and faculty. **Operational planning**, which will depend on the structure, organisation and characteristics of each faculty, is not covered by these Guidelines, not even in point 4. The objective of the Guidelines is to set the criteria for these two points to be developed using a methodology that is coherent with the defined strategic plans and objectives that derive from these, in a rigorous, non-arbitrary and documented way; the Guidelines cannot give details on which study programme, which teaching methodology or which models for evaluation should be introduced. The authors of these Guidelines believe that there may be different ways to plan the study programme, all of them valid provided that the above-mentioned principles are followed.

2 Training in Chemical Engineering

2.1. Chemical engineering today

The concept of *Chemical Engineering* is polysemic, like many other terms linked with education and the professions. The concept refers to an area of knowledge or **discipline**, with its own identity that is not covered by other disciplines. The same term also refers to a **profession** or, more particularly, a group of professions that apply this knowledge, in conjunction with other sciences and technologies. The same term is also used for a recognised degree subject. Some **training institutions/faculties** and different departments are named after the discipline. It is also the name of one of the **areas of knowledge** used to classify teachers and researchers in Spain.

Chemical engineering as a profession and discipline has been defined in many ways since it was differentiated from previous disciplines and professions, which was around 1880 in Great Britain. The first definition appearing on record is that of **G. E. Davis** (1901):

> Chemical engineering deals with the entire body of chemistry used in manufacturing.

The broader, more descriptive and explicit definition, albeit somewhat old-fashioned, of the **Institution of Chemical Engineers** in the United Kingdom is, in our opinion, the most useful for focusing on the framework, contents and characteristics of the profession:

> Chemical engineering is a branch of engineering involved with processes in which matter undergoes a change of composition, energy content or physical state; processes for processing matter; products that result from processing, and their application to achieve useful objectives.
>
> Chemical engineering is based on mathematics, physics and chemistry, and its processes are developed on the basis of knowledge from these sciences, other branches of engineering, biology and the social sciences.

> The practice of chemical engineering consists of conceiving, developing, preparing, innovating and applying its processes and products; the practice of chemical engineering also involves the economic development, design, building, operating, control and management of chemical plants, and research and teaching in all of these fields.

A recent definition, which introduces a new shade of meaning to how the field of chemical engineering is conceived, is that of **J. Gillet** (2000):

> Chemical engineering is the conceiving, development, design, improvement and application of processes and their products.

In this definition, it is "processes" and no longer "chemistry" that appears. This is the current view held by most training institutions in this field. Chemical engineering is a general discipline, the particular field of which is *all kinds of processes and products.* It thus includes metal materials and polymers, chemical products, fertilisers, food, medicine, cosmetics, paper, textile fibres, rubber, oil and its by-products, processes for obtaining energy, processes for the nuclear power industry, and also water treatment and solid waste processes, biotechnology processes and many others, together with everything that, with a more or less technological component, serves these sectors. This definition goes beyond the limitation that, to a certain degree, used to associate chemical engineering with the chemical industry, understood to be the industry that manufactures domestic and industrial chemical products.

In fact, according to the current Spanish economic activities grading (*Clasificación National de Actividades Económicas*, CNAE-93 rev. 1, **Ministerio de Economía**, 2003), chemical engineering is a profession referred to in many manufacturing and treatment activities: the refining industry (chapter DF of the CNAE), the chemical industry (24), recycling (37), gas (402), water catchment and treatment (41), hazardous goods (63122), sewage collection and treatment (9001), other types of waste (9002) and sanitary waste (9003). It also plays a leading role with other professions in many other sectors, such as the extraction of energy products (CA) and other minerals (CB), metallurgy (27), engineering (74202) and education (8022, 80302 and 80303), amongst many others.

This overall multisectorial approach to the profession and discipline of chemical engineering has been theorised since the eighties in different reports and academic articles, such as the well-known **AIChE** (1981), ***The Amundson Report*** (**Amundson**, 1988), ***The Septenary Committee*** (1985), the report by the **ECC** (1990), **Angelino** (1990) and **Charpentier** (2003), amongst many others.

The type of company where chemical engineers are very much sought after, and will probably continue to be in the future as well, are the competitive *large advanced companies* and, above all, technology-based SMEs with an important research and innovation component. The chemical engineer's *diversity of functions* is also considerable in these companies, in the chemicals sector or any other. The AIChE website describes eight different functions of a chemical engineer in industry, the services industry and public administration. The variety of these functions will influence the type of training that needs to be proposed in the programme specifications. Data from two surveys on placement in the labour market of public university graduates in Catalonia (AQU Catalunya, 2001 and 2005) corroborate previous assessments, as can be seen from the following.

Table 1. Data from the placement survey (2001 and 2005)

- The **rate of employment** is high (95% for chemical engineers and 91% for industrial engineers specialising in industrial chemistry). All graduates that were interviewed found work on completing their studies.
- The **sector of economic activity** is very disperse (even more so than for industrial chemical engineers). Only 24% of all chemical engineers are in the chemical or pharmaceutical industry, and 31% of industrial engineers in industrial chemistry. The majority of graduates (59%) were in the secondary sector and 41% in the services sector.
- With regard to the **type of company**, most graduates work in the private sector (85.7% of chemical engineers and 90.9% of industrial engineers in industrial chemistry). Only 8.5% of graduates work in companies with less than 10 employees, whereas 25.4% work in companies with more than 500. The majority work in medium-size companies with between 11 and 500 employees. In geographical terms, the number of employees in companies in the provinces of Barcelona and Tarragona is slightly higher than in Girona, and graduates working outside of Catalonia work more in large companies.

- In terms of their **job functions** three years after graduating, only 9% of chemical engineers had managerial functions, and curiously the percentage was higher for industrial engineers in industrial chemistry (13%); this was the situation according to both placement studies that were carried out. The job functions of graduates are mainly technical (43% of chemical engineers and 29% of industrial engineers in industrial chemistry) and other qualified job functions (23% of chemical engineers and 39% of industrial engineers in industrial chemistry). 15% of all chemical engineers and 7% of industrial engineers work in R+D, whereas the percentage for commercial job functions is much lower.

A degree in Chemical Engineering is also a good pathway to positions in top management where there is a technical basis. It is well proven that it is feasible to build a management curriculum on a scientific or technological foundation, although it is not usually so the other way round. Chemical engineers also find themselves *coinciding* and in *competition* with many other degree holders in the labour market. It is not always knowledge or competences that lead an employer to choose between the holder of one type of degree or another; the determining factor is often the company's long-standing tradition, the employer's own studies or other non-rational factors.

The structure of the business world, especially in the case of large companies, has changed considerably over the last decade. Phenomena such as globalisation, and company focalisation and specialisation have led companies to shift their assets in order to concentrate on activities that they are better prepared to deal with. On the other hand, the influence of communications technologies, the new global European market, concerns about the environment and sustainable development, safety at work, public health and people's well-being have regenerated companies in many fields. In addition to changes in the production system and staff organisation, companies have gone to great efforts to approximate their clients' needs, which has led to greater diversification of products closely linked to developments in the market. New companies, and certain divisions of long-established companies, are increasingly putting the emphasis on new aspects linked to product and process production and design. Change and flexibility therefore need to be taken into account as a component throughout the entire training in chemical engineering.

2.2. The objectives of training in chemical engineering

The old idea that a complete and valid initial training is essential for all types of situation in the future is now obsolete, despite the fact that it still pervades the minds of some people and approaches in certain subjects. Life-long learning (or L3) is today an unquestionable and non-controversial need in all fields and professions. This need has been dealt with on a political scale by all administrations, and is expressed in concrete terms in proposed European legislation (the Bologna Declaration and all documents deriving from this, the *Tuning Report* and others) and Spanish and Catalan legislation (*General guidelines for integration in Europe*, AQU Catalunya, 2003).

The objective of basic training in chemical engineering is to train professionals in the following characteristics:

- To be creative, versatile, adaptable, communicative and capable of team work.
- To be capable of working in the process industries in any sector, in companies and organisations that serve these sectors, or to be capable of setting up their own company on the basis of entrepreneurship.
- To be motivated towards life-long learning to be capable of adapting to a changing industrial and social environment.
- Ethically speaking, to be motivated to contribute to the well-being of society, people's health and safety, and sustainable development.

Life-long learning covers different stages:

- Basic infant, primary and secondary school education.
- Pre-university education.
- Recognised university training (first, second and third cycles).
- Continuous training.

With regard to programme specifications for university subjects, the three recognised cycles proposed in the new regulatory scheme (Bachelor, Master and PhD) are all professionally orientated, with job opportunities in the labour market at each level and the possibility of further recognised as well as on-going training at any time in one's occupational activity. As far as this document is concerned, the focus is obviously on the recognised university sphere, and more specifically, the Bachelor + Master; nevertheless, this does not obviate the importance of pre-university training, in that it determines the students' level of entry, and also the advisability of greater coordination between continuous training and recognised training that is on offer.

University training in chemical engineering has changed in parallel with industrial needs. Its development can be summarised in various stages that are inseparably linked with mathematical model-solving capabilities:

- The pre-engineering stage, which was dominated by descriptive industrial chemistry, was followed by an **initial engineering stage**, in which **unit operations**, first defined by Little and Walker (1915), began to be modelled. What up until that time had been the mere description of an endless number of processes and products turned into the study of unit operations, with simple mathematical tools that use equations of conservation, state and design, with overall and individual transfer coefficients. Unit operations and their study constitute the **first paradigm of chemical engineering**. This paradigm was completed from the fifties onwards with the concept of chemical unit operation and its subsequent development (Levenspiel, 1980).
- From 1960 onwards, the application of the three **transport phenomena** on the microscopic scale was developed for operation and process design. This is the **second paradigm** of chemical engineering, which includes the concepts of contact mode, population balance and the profile of properties. The level of mathematics in modelling increased considerably, together with the difficulty of model solving, and generalisation became increasingly apparent and there was a gain in the level of science but with a loss in immediate applicability.

- The development of new experimental and theoretical tools has enabled design to be dealt with using even more basic principles and descriptions, which deal with the atomic/molecular description and study of turbulence and the measurement of fluctuations in velocity, temperature and concentration. The mathematics have become even more complex and immediate applicability more remote, although the level of generalisation does allow problems to be dealt with that were unattainable with the previous levels of description. This is the **third paradigm** of chemical engineering, which, complemented with appropriate techniques, permits the solving of complex problems at both the micro and macro scales, which is currently attainable using present-day computer techniques.

Chemical engineering has incorporated subjects from other scientific and technical fields, such as **dynamics** and process control, and synthesis and system **optimisation**, which are now genuinely considered to form part of chemical engineering.

The use of **computers** in industrial control and data collection processes, together with the new calculation and simulation facilities, has considerably modified both the contents of training in chemical engineering and the way these contents are acquired and changed the subject and the profession itself in many areas. This aspect is so decisive that it cannot be dealt with briefly here, and mention is made of it here just for the record.

The increasing degree of complexity, conceptualisation and abstraction of the successive paradigms raises the problem of which pedagogical methodology should be used to train students who, in general terms, will have no industrial experience and be incapable of easily contextualising the instruction received. Particular account will need to be taken of this aspect in study programmes.

The vocation of chemical engineering as a discipline has been and continues to be general and, covering a broad spectrum, it participates in the programme specifications of many different subjects. Different programmes, deriving either from chemical engineering or an independent source where chemical engineering has made a truly authentic contribution, have developed into a series of thematic clusters: biotechnology, environmental engineering, environmental science, materials engineering and food science and technology are examples of current programmes with an important chemical engineering component.

2.3. The programme specification. General ideas

The first cycle degree, or **Bachelor in Chemical Engineering**, according to the new EHEA-adapted nomenclature, which has generic and transversal characteristics, comprises both the current degree in Industrial Engineering, with specialisation in Industrial Chemistry (currently first cycle), and the current Chemical Engineering degree (currently first and second cycles). The duration of the degree is established in the corresponding regulatory system. 180 credits, including obligatory credits, are required in this degree for access to the Master's programme. The Bachelor degree needs to be professionally orientated, although it is acceptable, in certain cases and faculties, for it also to be orientated towards further study of a Master's degree.

Different **Masters** programmes (second cycle) that stem from the graduate programme are either professionally or research orientated, which are possibly subject or component orientated, advanced, and probably correspond to subjects that are partially offered today as second cycle and certain postgraduate programmes. In addition to the Master's degree in Chemical Engineering itself, other examples include Materials Engineering, Food Science and Technology, Environmental Engineering and possibly the current degrees in Biotechnology and Environmental Science. Many of these study programmes will continue to exist with the new spectrum of programmes as first cycle or Masters programmes. Masters programmes stemming from the first cycle Chemical Engineering programme with these subjects will therefore need to be distinguishable from and complementary to these studies, with a large technical component for industrial application purposes.

The training programme should be determined by the definition of the professional and academic **competences**, and not confined to academic tradition nor subordinated to advanced research matters carried out in the faculties. The various social partners involved should take part in defining them, especially employers and working graduates, together with academics, the corresponding professional bodies and the Administration.

One competence that needs to be developed is **entrepreneurship** and the setting up of knowledge-intensive companies, based either on innovations developed at the university itself (spin-off) or the use of market opportunities. In this respect, policies need to be developed by the universities, employers' organisations, professional bodies and public administration.

The training methodology must give prominence to three aspects linked to the realities of the profession:

- The setting out of **real problems** to be solved within a set time limit, such as projects, industrial problems, final-year projects (company or applied research-linked), working and discussion groups dealing with real situations, and many other options to be explored.
- Real-life contact with industry, with the promoting of visits, stays and work experience/placement in **companies** of appreciable duration, which are truly supervised and tutored by academic staff, with specific objectives and planning that is as rigorous as possible. Learning relationships of accountability and authority, complying with deadlines and decision-making in the total absence of information are aspects that are very difficult to simulate in the academic world.
- The involvement of industrial professionals in defining and teaching the programme, through assistant teaching staff or a similar category, is considered to be essential in the real training of future professionals.

3
The competence profile of Chemical Engineering

Defining the profile of competences is a key step because the profile is the basis on which the whole series of training activities for obtaining the competences is developed. Competences in the profile therefore need to be established as rigorously and objectively as possible, and on the basis of evidence where possible. In the case at hand, a large part of the available evidence is opinions on the skills and knowledge to be developed by the programme specification so it is essential to assure the quality and representativeness of those providing the information.

Consultations with the academic community and the professional and labour market sector regarding the programme specification make it possible to validate the training programmes. The information obtained also provides complementary opinions, and others aspects can be detected that would possibly be overlooked in an initial draft. Consultations are also a good opportunity to disclose the programme specification to both groups.

3.1. The consultation process

3.1.1. Groups to be consulted

The three main stakeholders, namely, graduates, teaching staff and employers, need to be consulted.

- The **teaching staff** must be the actor and agent provocateur of change. They are familiar with the body of graduates they are training, and they also know the advances and development in the contents of the academic disciplines involved. One matter to be decided on is whether to just consult the teaching staff of the core subject departments of the programme, or also the teaching staff of all the departments involved in teaching the programme curriculum. In the case of the DISSENY programme Chemical Engineering group, in addition to teaching staff in chemical engineering departments, teaching staff were also included from other departments who were personally more involved in teaching Chemical Engineering studies.
- The suitability and coherency of a programme specification must also be assessed by those outside of the educational system, i.e. **graduates** and **employers**. These two groups are in a position to confirm how useful the programme specification is to them. The employers group is particularly relevant for the programme in Chemical Engineering, and in general for any kind of engineering, because engineering is defined precisely by the vocation with which it is applied within the industrial sphere. With regard to graduates, recent graduates who specifically were interviewed because they are more capable of taking account of the training programme they have just completed. A distinction was made between grant holders, those working in private enterprise, and the unemployed. A distinction was also made between replies from those who had taken different current degree programmes: industrial technical engineers, chemical engineers and industrial engineers.
- **Students** were not consulted because it was considered that they lack a clear view of the overall programme specification and the suitability and appropriateness of the profile.

3.1.2. Instrument

A list of competences and professional characteristics was drawn up and used to prepare a questionnaire with four groups of items or questions (see the annex 2). Each item was given a score in a scale from 1 (very little importance/not at all relevant) to 4 (very important/highly relevant).

Table 2. Scope of the questionnaire

Item groups in the questionnaire	Number of items
Fundaments of science	6
Practical skills	15
Transversal competences	
■ Interpersonal relationship competences	5
■ Communication competences	3
■ Personal competences	2
Total	**31**

For all groups, space was left where additional unconsidered competences could be entered.

In parallel to this, an accompanying letter to be sent with the questionnaire was drawn up, explaining the aim of the DISSENY programme and pointing out that the information received with the results of the consultation process would help to better define the profile of outcomes for the graduate in Chemical Engineering.

3.1.3. Sample

Each member of the working group was given the job of collecting the questionnaires from the teaching staff and graduates in their faculty. The process of consulting employers was centralised.

Between December 2004 and March 2005, a total of 165 completed questionnaires were collected, which were distributed as follows:

Table 3. Groups consulted		
Teaching staff	94	57%
Graduates	48	29%
Employers	23[1]	14%
Total	**165**	**100%**

3.1.4. Analysis of the results

The descriptive analysis of selective answer responses showed the wide acceptance of the proposed competences belonging to the profile, which is not surprising as this refers to the essential core competences of the chemical engineer and takes in, to a large degree, the competences proposed in other recent studies on professional profiles that are particular to Chemical Engineering already agreed to and recently developed, such as the Working Party on Chemical Engineering Education <http://www.efce.info/wpe.html) of the European Federation of Chemical Engineering <http://www.efce.info/) and the White Paper by the Agencia Nacional de Evaluación, Calidad y Acreditación (pending publication).

In cases where the mean was low but with a high discrepancy between employers and teaching staff, it was agreed that special consideration and prevalence be given to the opinion of employers, more especially as one of the key objectives of the new approach of programme specifications is to bring about a greater transfer between what is learned in the classroom and what is necessary in the labour market.[2]

Following the analysis of the open-response questions, the committee decided to include two new competences in the profile and modify the wording of two others. The definitive version of the profile is given below.

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[1] Of these completed questionnaires, 15 were sent by e.mail (out of a database of 51, i.e. 29%) and 5 by post (out of a total of 68). E.mail was therefore a good means of contact for the employers group, probably because it is easier to reply, in spite of the loss of anonymity.

[2] This was the case with "Appropriate knowledge of relevant legislation and regulations", which had the lowest mean due to the low rate of assessment by teaching staff, but with a much higher mean for employers and students. Although the working group agreed that it does not make sense to "explain" articles in the regulatory system, the employers opinion was included because it is necessary for future professionals to understand that the regulatory system determines their work; it is not a question of making legislation a course to be studied but for it to be included in courses as an essential framework for the training.

3.2. The programme specification for the chemical engineer

Table 4. Fundamental scientific knowledge and competences in the laboratory

- Have the capacity to use the knowledge in the programme specification to analytically, numerically and visually establish and solve a variety of typical chemical engineering problems.
- Have relevant knowledge of the basic sciences and in particular mathematics —including statistics—, chemistry, biology, physics and economic principles, for understanding, describing and solving typical chemical engineering problems.
- Have sufficient knowledge and criteria about organic chemistry, inorganic chemistry and physical chemistry, biochemistry and materials science.
- Understand the principles on which modern methods of chemical analysis are based, their limitations and applicability to chemical processes.
- Know the different reaction, separation, transport and circulation processes of fluids and materials processing involved in industrial processes of chemical engineering.
- Understand the main concepts of process control in chemical engineering.

Table 5. Specific competences

Specific theoretical knowledge

- Understand the fundamental principles on which chemical engineering is based:
  - Balances of matter, energy and motion.
  - Thermodynamics, between-stage equilibrium and chemical equilibrium.
  - Kinetics of the physical processes of mass, energy and motion transfer, and chemical kinetics.

Specific practical competences

- Have the ability to design chemical engineering processes, equipment and installations.
- Have the ability to analyse complex problems in the field of chemical engineering.
- Be capable of judging the economic viability of an industrial chemical engineering project.
- Have the capacity to use the knowledge and above-mentioned competences to prepare a chemical engineering project.

The impact of the profession

- Understand the central role of chemical engineering in preventing and solving environmental and energy problems, in accordance with the principles of sustainable development.
- Assess, in a structured and systematic way, the hazards for safety, health and hygiene in a process that either exists or is in the design stage, and apply relevant measures.
- Be capable of understanding the impact of engineering solutions on the environment and the social context.
- Have assumed the values of responsibility and professional ethics that are characteristic of chemical engineering.
- Appropriate knowledge of relevant legislation and regulations in all situations.

Competences in research

- Interpret experimental situations and actions.
- Plan, carry out and explain experiments in the different areas of chemical engineering, and know how to inform about them.
- Know how to use the scientific and technical bibliography and sources of relevant data.

Table 6. Transversal competences: personal, interpersonal and instrumental

- Be independent, dynamic and organised, and capable of analysis and synthesis, critical analysis and long-term planning.
- Have a high self-esteem and frustration tolerance.
- Be results-orientated, with the ability to solve problems where there is a lack of evidence, creative, and capable of initiative, decision-making and dealing with information.
- Have the capacity for self-assessment and constructive self-criticism.
- Be capable of learning on one's own. Recognise the need for life-long learning and possess an active attitude to do so.
- Willingness to accept corporate culture and know how to adapt to the structure and forms of procedure (decision-making systems, relations with colleagues and management, predisposition to take risks, etc.).
- Keep up to date with innovations in one's own professional field and know how to analyse future trends.
- The capacity to be innovative when acting in response to new circumstances and new organisational systems, as well as facilitating optimisation of the production process.
- Ability to communicate effectively, clearly and concisely, orally and in writing, using presentations with appropriate support materials, and to adapt one's style and language content to the person who one is speaking to or the auditorium.
- Have leadership and negotiation abilities, be capable of using relevant activating resources to direct and lead working groups, motivate collaborators, generate empathy and negotiate.
- Capable of team work and adapting to multidisciplinary and international teams on different scales.
- Be acceptably fluent in English to communicate and relate socially, and knowledge of another relevant world language.
- Experience with the use of appropriate generic and specific software for chemical engineering.

4

Guidelines for preparing a programme specification for the bachelor in Chemical Engineering

This chapter gives the guidelines for designing curricula for a specific degree programme at a particular university. It starts with a series of considerations on what the curriculum design should be based on, and goes on to present a series of items to be taken into account when designing the study programme. This approach presupposes that the rate of accomplishment will give an idea of the quality of the programme design, and also the quality of the institution and the university that has designed it.

Preliminary considerations in relation to preparing a programme specification for the Bachelor in Chemical Engineering are as follows:

- **Implications of the concept of life-long learning (L3)**: Life-long learning is assumed to be a structural element of the training. The training perspective whereby information is given to deal with any foreseeable eventuality in any situation is considered to be obsolete. In terms of the new perspective, it is therefore erroneous to try to prepare complete and thorough specifications for Bachelor programmes because an individual's training requires a broad and comprehensive perspective. A multi-scale perspective appears to be the most efficient. The core training should provide an understanding of how the different frameworks of description and scale in chemical engineering work and interrelate; for example, how the different kinds of unit operation work, what additional information can be used to describe, at the microscopic scale, the transfer phenomena that take place, and how this fits in with other scale operations in a complete plant. Nevertheless, it is impossible for the training to be presented in such a way that the graduate knows, to the same level of detail, all of the operations, all transfer mechanisms and how to integrate all operations into a complex system that includes regulation and control systems.

- **Basic training and applied training**: Graduates must have sufficient tools when entering the labour market. However, this does not imply a training in specific valid prescriptions or applications for a particular moment in time that will become obsolete within a short time. The student should be provided with the capacity to carry out reflective actions and the capacity for self-criticism. For example, and underlining the comment in the previous section, it is not necessary for the graduate to really design a reactor but to understand the basis of the design.

- **Abstraction and concretion**: Due to limitations of time, it is sometimes impossible to explain everything that makes up the complete body of teaching in a particular subject. In situations such as this, the level of abstraction of the contents is often increased by a degree: for example, seeing that there is not enough time to see all of the between-stage equilibrium unit operations, a sequence of generic equilibria that is applicable to any operation is used without setting it in context in relation to any of them. Such a generalisation, which is very correct and necessary, would not appear to be good pedagogical practice, given that conceptualisation should be based on the prior knowledge of what one wants to conceptualise, and one thing cannot be replaced by the other. The capacity demonstrated by students to mechanically solve complex mathematical models is not necessarily linked with an understanding of the reality described by the mathematical model, which is what should be the intention of their learning. There is consensus amongst experts that this type of training discourages the student and prevents him/her from understanding reality. Along the same lines as the previous comment, it has been proposed that certain general yet at the same time highly abstract subjects, such as transport phenomena, be reserved for the Master's, and not the undergraduate, programme.

- **The student's motivational impetus**: Motivation is a fundamental element in facilitating the programme, right from the moment of the student's first contact with it. For this reason, the proposal was made for the programme to have a clear engineering perspective during the first year —such as that given in the matter and energy balance course— instead of providing basic tools like mathematics and physics in a decontextualised way. It would be highly interesting if the problems dealt with in these courses, especially mathematics, were related to the everyday life of chemical engineering, such as, for example, considering how to solve representative differential equations. In any case, recent experience on the training of new students in basic tools shows that total decontextualisation is difficult and these will possibly have to coexist. An understanding of the fundaments will result in greater enthusiasm once the ways to apply the concepts are mastered.
- **Sequencing from the pedagogical perspective**: As far as curriculum organisation is concerned, the most appropriate curriculum is one that meets the needs of the students' learning as much as possible. While the approach of starting the programme with a strong basis in the fundaments in order to ensure that subsequent applications are well understood is conceptually logical, in terms of methodology it is considered that understanding is achieved when the student can start out from personal experience and, when he/she sees the need, use certain tools. Recourse to these is made in elements to motivate learning. The fundaments acquire significance once the student is aware of their usefulness.

4.1. Preliminary stage. Definition of the framework

The preparation of any programme specification has to fit into a general framework for degrees that is defined by the university and faculty, and also the university's mainstream of decisions and its particular teaching policy. The series of actions that should be carried out prior to designing the Chemical Engineering study programme are accordingly summarised below.

- Generally speaking, it is the **university** that makes the final decision concerning what its most desirable catalogue of degrees consists of. The main factors to be taken into account for preparing a programme are, amongst others:
  - The university's strategic plan, which will need to be based on its estimated future prospects, the type and quality of the university's external relations with its particular social and labour market environment and the university's mission.
  - The spectrum of current evaluated programmes and coincidence with programmes at other universities.
  - Data on graduate placement in the labour market for the various current programmes and anticipated demand for graduates in these and related programmes in society in Catalonia, Spain and Europe.
  - Detailed analysis of data on the socio-economic environment.

- The **faculty** is responsible for proposing and deciding on the structure of the programmes that it has been assigned. The main factors to be taken into consideration, amongst others, are:
  - Factors in the previous paragraph that are relevant to the faculty, especially the university's mission in accordance with its socio-geographical setting.
  - Applying and developing the university's strategic plan at the faculty level.
  - The availability of current resources, in terms of staff, facilities, transferable know-how, external relations and foreseeable deficiencies.

- The **department** is responsible for decision-making concerning the contents and activities of the subjects that it has been assigned. The main factors to be taken into consideration, amongst others, are:
  - Factors in the previous paragraph that are relevant to the department.
  - Applying and developing the university and faculty's strategic plan on the departmental scale.
  - Available material and human resources, and detailed know-how.

- Elucidate the relation between research, teaching and services in all spheres, and the impact of research on teaching at the Bachelor level.

Prior to preparing a new study programme, the university must define various general aspects and mechanisms, the most fundamental of which are given below.

4.1.1. The quality assurance system

The model for quality assurance used by the university must also anticipate the design of new programmes. We confine ourselves here to point out that, in each particular case, the contents and suggestions made in these Guidelines will need to be adapted to the situation and mechanisms approved and implemented in each university and faculty. See point 4.3 for more on this aspect.

4.1.2. Details of the design of study programmes

These should consist of the following:

- The responsibilities of the faculty and department in the design stage.
- The organisational lay-out of the design mechanism.
- The definition of the strategies and applicable activities, available resources and the system for requesting new teaching requirements as a result of the new study programme.
- A rigorous and realistic application schedule.
- The procedure for modifying a programme specification.
- The procedure for evaluating the design process.

4.1.3. Training of teaching staff and administration and services staff

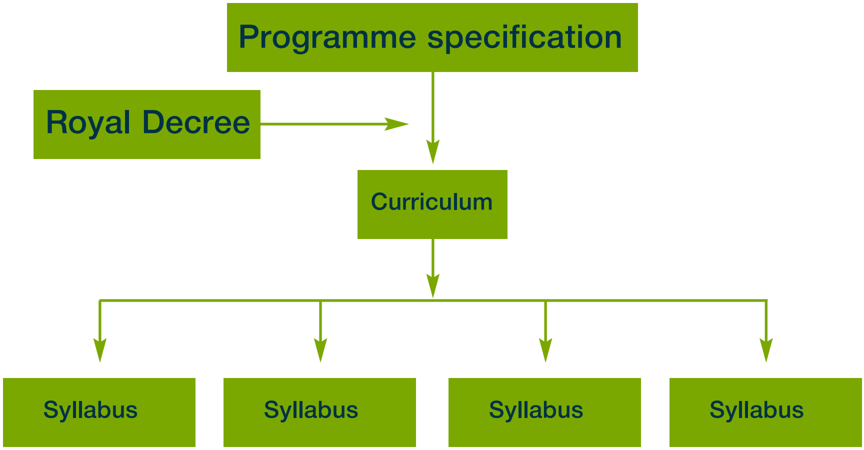
This is an inseparable aspect of the preparation of new study programmes, particularly with the conceptual and methodological change entailed in the process of European convergence in the EHEA and the European credit transfer system (ECTS). This is not dealt with in this document, although it is important to underline the need for specific training regarding the suitability of practical work, work/placement experience and the final-year dissertation, which are more specific aspects of technical and scientific programmes like chemical engineering. Teacher training is a particularly important aspect, as well assistance for senior teaching staff to adapt to new methodologies and new teaching approaches. This matter needs to be dealt with by the university as a whole, in compliance with the specific training needs of the faculty and teaching staff.

4.2. Design stage

This is the specific stage in the guidelines for preparing the programme specification, and reference is made to the three preceding chapters. Well defined protocols will be required in the preparation process in order for it to be of high quality, adapted to specific social needs and, at the same time, accepted by all of the teaching staff and administration and services staff that will have to implement it. The intention of the various protocols suggested below is that they be coherent, complete and inspired by the most recent philosophy for preparing a programme specification, i.e. to use the required competences and training contents in defining the study programme and teaching strategies that will need to be used.

The stage for preparing the study programme can be broken down into four different phases:

- Deciding on the methodology to be used in the preparation process.
- Specifying the competences to be acquired in the Bachelor degree programme.
- Selecting the contents to be studied in the Bachelor degree programme (curriculum) and putting them in sequence.
- Deciding on the methodologies to be used by the teaching staff (syllabus).


Programme specification
Royal Decree
Curriculum
Syllabus
Syllabus
Syllabus
Syllabus

4.2.1. Deciding on which methodology to use for the design process

The preparation of a new programme specification is an important moment in the life of the university community, when hopes and expectations for improvement are raised in the promoter group, and also the time when calls to increase specific contents are made by those who consider them to be important and undervalued in the preceding study programme. It is necessary to ensure that the inevitable clash of interests and opinions becomes a source of creative ideas and not a permanent and sterile confrontation.

The process of generating a programme specification is also a complicated balancing act between the needs for training, available human and material resources, and external constraints —total duration, structure and contents set by higher authorities, maximum and minimum number of credits to be acquired in a year or term, amongst many others—, which make it impossible to complete the preparation process until almost everything is agreed to and, moreover, in a simultaneous way. Legislation is very flexible in terms of subjects and courses, however, and this gives great freedom to those actually preparing the specification, as well as enabling them to find satisfactory solutions that are very different from one study programmes to another.

This flexibility provides for the distinction between degrees in a particular programme offered by different universities, it enables programmes to be adapted to different circumstances and determining factors, and different pedagogical and organisational criteria can be taken advantage of as well. This flexibility and freedom can however lead to poorly prepared study programmes that have little internal coherency: on too many occasions, the solution is used —convenient because it is a compromise, but inefficient and incoherent— of including subjects or courses called for by some group or teacher quite simply by slightly reducing other subjects, which accept the reduction to keep the social peace.

It is fundamental to choose a correct, complete and coherent methodology in order to assure the quality of the design. The design philosophy underlying these Guidelines —and the entire convergence process in the EHEA— has already been repeatedly explained although it is useful to be reminded of the four main points in order of sequence:

- The programme specification is an instrument for society —especially employers— and it is necessary to have their explicit opinion.
- These needs are expressed in terms of competences to be obtained by students on graduation.
- The programme specification has to be prepared explicitly to ensure that the competences required of graduates by society are attained.
- The contents to be given and the methodologies to be used are instruments for the competences to be formed.

The preparation process, therefore, must ensure that this sequence is complied with, bearing in mind the limitations and perspectives pointed out above. Therefore, as a preliminary yet fundamental point when defining a programme specification, the overall procedure must be defined and documented. This means that the detailed planning of the process must be explicitly approved, with appropriate documents, by the appropriate body. Table 7 gives a list of the main aspects to be considered.

Table 7. Planning the process of designing the programme specification

- Who leads the process and which mechanism is to be selected
- The organisational chart of the process
- The timetable or calendar for the process
- The composition of the working groups and committees
- What decision-making mechanism is to used
- What interaction is there with lower and higher educational levels in the design process
- What interaction should there be with university structures for teaching and training, such as educational science institutes, careers guidance offices, etc.
- What requisite documentation needs to be produced at each phase and stage
- Who takes care of and disseminates the documentation
- Who is given the documentation that is produced
- How much publicity is given about the process to all teaching staff, service and administrative staff, students, and people and entities outside the faculty
- What consultation and feedback mechanisms are conceived to prevent short-circuits in information and decisions not reached due to lack of consensus

Different rules and regulations, traditions and styles in faculties mean that just one methodological model cannot be given, although one must bear in mind that defining a programme specification is a complex process that needs to be dealt with in a professional way, using appropriate ICT and managerial tools. The use of standard management software for projects and internal communication, together with an appropriate number of on-line discussions and actual meetings, may speed up the process and enable actual meetings to be reserved for the important moments of decision-making.

4.2.2. Specifying the competences to be obtained in the Bachelor's degree

The generic competence profile for the Bachelor in Chemical Engineering is given in chapter 3 of these Guidelines. Each faculty, when considered to be appropriate, needs to **specify** the generic **competences** and make the decision concerning which specific competences have to be acquired by its graduates, i.e. **the faculty's own competence profile**. Official directives concerning the programme will be given by the *Consejo de Universidades* (Spanish Universities Council), although there is no alternative but for them to be non-specific and greater precision will be necessary within the scope of each university. The decision on the required competence profile or profiles for the Bachelor degree, from both the academic and professional points of view, needs to be made rigorously and on the basis of documentary evidence.

There are three reasons why it is important for the faculty to specify the competences:

- For the value in itself of the information gathered.
- For the dynamic generated by the process of the competences being specified between the working groups that manage the defining process.
- Because of the image given by the faculty in terms of its seriousness and willingness to come closer to the realities of society.

Table 8. shows a possible outline for planning the specification of competences.

Table 8. Planning for the specification of competences
■ Decision on the need or not for a higher level specification of competences
■ Gathering of available information, in contact with the corresponding university and external bodies (national and international)
■ Assimilation and summary of the previous information, and diffusion of the results as planned
■ Drawing up of the proposal specifying the specific and transversal competences required of graduates
■ Preparation of the consultation process of employers, teaching staff and recent graduates, with the appropriate representative selection
■ Evaluation of the completed questionnaires and drawing up of conclusions
■ Divulging of the results as planned, especially amongst those participating in the consultation process
■ Final drawing up of the required competence profile for the Bachelor's programme

There are different types of documentary evidence, such as data on graduate placement from similar programmes, evaluation documents of a preceding similar programme that the new programme replaces, formal interviews with employers, expressions of interest by companies and employment placement offices, and any other valid pertinent data. Useful data may be obtained from reproducing the process described in chapter 3 within the scope of the faculty, and consulting the university's social council and/or board of trustees, the faculty's advisory board, former students, related professional bodies and corresponding employers associations, provided that consideration is given to the representativeness of the data.

In programmes such as chemical engineering, one professional opportunity for the recent graduate, at least for a certain time, is that of an academic career by way of the Bachelor-Master-PhD pathway. The teacher is thus not just a trainer but also an employer, in the sense that a significant percentage of graduates shortly afterwards form part of the research groups directed by the same teacher. This twofold role as trainer and employer can give the teacher a perspective of the competences to be obtained that is too biased towards aspects that are more theoretical or to do with research, which must be avoided. The best way to avoid this is to make clear this professional opening for the graduate and to treat it the same as the other ones, with the specific competences required and the need for training and appropriate methodologies, with the importance given to it in the programme as a whole that is considered appropriate.

4.2.3. Selecting the content to be obtained in the Bachelor's programme

Degree content, and Chemical Engineering is no exception, is, from the classical point of view, almost the sole element of a study programme. The "matter to be explained" works on the principle that university education is a transmitter of contents by way of master classes and use of the blackboard, and memorising and the understanding of contents are the main basis for evaluation.

According to the way that the programme specification is currently conceived, the defining of the contents is equally important as they are considered to be the specific language of the programme and the professions that the programme serves as a training for: the concepts, terms, data and relationships between all of these that, as a whole, the degree holder much have significant knowledge of. Mere encyclopaedic knowledge obviously does not imply the ability to know how to use such knowledge appropriately, and this is why it is not enough to conceive education as a simple content transmitter when forming competent graduates in a particular speciality.

In Chemistry and Chemical Engineering programmes, amongst other experimental and technological programmes, importance was traditionally given to problem-solving classes —also considered as forming part of the contents— and class laboratory experiments, the only time, aside from contents, when the student developed skills in an explicit way. Classes in the use of computers and documentation do the same.

The general directives common to all programmes are lists of minimum contents to be taught. Following the guidelines of previous study programmes, these contents are organised according to subject, with certain flexibility in the planning of the courses that derive from them. The faculty will therefore need to determine what complementary contents need to be imparted in accordance with the different approaches to the desired programme specification. The appropriate sequence of contents based on the level and complexity of the concepts is important to ensure that learning is based on understanding.

The decision on the contents cannot be made regardless of the decision on teaching methodologies, strategies and activities, and they all depend on the competences to be obtained.

4.2.4. Deciding on the teaching methodologies, strategies and activities to be used

From the terminology point of view, the term *teaching methodology* is often used to refer to broad theoretical approaches on the basis of which resources and activities are organised. Examples of this are the ECTS system, practical learning and expositive teaching. *Teaching strategies* are the means with which methodologies are developed. Examples are the work strategy for projects, master classes and the laboratory. *Activities* are the specific elements used to develop strategies and involve work for the teacher and work for the student. Examples of activities are writing up a plant visit report, reading articles and setting problems to be solved in class.

A considerable variety of teaching practices exists and most of these are regularly used in experimental and technological programmes, although not systematically enough. The job of preparing the programme specification consists of appropriately combining the competences to be obtained, the contents to be given and the available strategies and activities. The final objective is to obtain a final curriculum proposal that is arranged in sequence and structured according to courses or learning units, with each one described in terms of formative contents, activities to be carried out and the procedure for evaluation.

There are two possible approaches to the design. The first, and more classical, consists of structuring the contents in subjects and courses and deciding on pertinent strategies, activities and evaluation procedures. A subsequent analysis of the structure that is obtained will help to judge which generic, subject specific and transversal competences have led to the design. Comparison with the originally sought after competences will enable shortcomings to be detected in the design actually applied and corrected by modifying appropriate strategies in particular subjects in order to better approximate the required competence profile.

A second approach, which is not so usual, consists of starting with the list of required competences, establishing which ones are optimum strategies to attain each competences and then put courses together by combining learning strategies and activities with the contents to be developed. This second way can lead to the malfunctioning of a programme specification and curriculum, it is difficult to implement in terms of timetables and calendar, and would also require adjustments later on to make it viable.

For both approaches, a clear explanation is required of the suitability of each type of activity and strategy for forming particular generic, subject specific and transversal competences.

In general terms, there are two main types of strategies and activities that can be distinguished: ones that are based on content transmission, such as master classes, and those that are more synthetic, such as project work, the final-year project or dissertation, the integrated laboratory, debate, tutoring, work experience/placement and plant visits, which help to form more transversal types of competence. The design of the programme specification has to appropriately combine activities, in terms of ECTS credits, to ensure the harmonious development of increasingly difficult contents and transversal competences that become increasingly like the ones to be applied in a professional context.

The most usual strategies and activities in the field of chemical engineering and the more outstanding competences that they develop are as follows:

Table 9. Strategies, activities and competences

Learning strategies	The student's activity
Master class, to transmit the basic structure of a subject	Take notes, diagrams, summaries Individual solving of tests and questions
Seminar or group work discussion	Case analysis Preparing a subject or oral presentation to be given to other students
Text analysis	Reading textbooks, journals, catalogues, regulations, with oral and written comments
Solving problems presented previously	Problem-solving
The supervised solving of more complex problems and mini-projects	Understanding the scope of the problem Search for information Problem-solving Case analysis Use of documentation in English
Specific laboratory experiments, with detailed explanations	Preparing the activity Carrying out the activity Making the report and presentation

Main competences (in addition to specific contents)
Grasping the significance, and subsequent structuring, of orally-presented information
Reflective and systematic individual study
Memorising and assimilating basic concepts
Deductive and analytical ability
Structuring of the available information
Ability to transmit contents
Discussion and synthesis abilities
Reading comprehension
The ability to sum up and summarise
Oral and written communication skills
Development of problem-solving strategies
The sense of reality in the results
Leadership
Search for outside bibliographical information
Ability to formulate and test hypotheses
Development of problem-solving strategies
The sense of reality in the results
Team work
Handling, observation, learning techniques
Taking samples; gathering, processing and interpreting experimental data
Safety, hygiene and waste management skills

Learning strategies	The student's activity
Integrated laboratory on open, more complex problems, in a group situation	Establishing the strategy to be followed Designing experiments Writing and presenting the written and oral report Use of documentation in English
Making an individual or group report on a subject	Search for information Writing up the report

Main competences (in addition to specific contents)
Handling, observation, learning techniques
Taking samples; gathering, processing and interpreting experimental data
Designing experiments
Drawing up technical reports
Safety, hygiene and waste management skills
Leadership
Search for information
Organisation and orderliness
Time management
Creativity
Team work
Oral, written and visual communication
Commitment combining precision, cost and time
Written communication skill
Preparing technical reports
Languages
Academic and industrial documentation

Learning strategies	The student's activity
Developing a directed group project or piece of work (possibly multidisciplinary between groups in different faculties)	Understanding the scope of the project Distributing the work among the group members Search for information Possible collaboration with students in other specialities Developing a specific piece of work Summarising individual pieces of work Drawing up and presenting results
Plant visits	On-site attendance Making a report

Main competences (in addition to specific contents)
Leadership
Industrial documentation, the regulatory system, legislation
Languages
The sense of reality and economy in processes
Creativity
Teamwork that involves peers and/or is multidisciplinary
Time management
Oral, written and visual communication
The use of the latest software for organisation, project management and sharing information
Practice with estimations, simplifying hypotheses and rules-of-thumb
Responsibility and professional ethics
Contextualising knowledge
Gathering non-structured information
Observation
Search for information
Knowledge of the realities of industry and the professional world
Preparing technical reports

Learning strategies	The student's activity
Work experience/placement in private enterprise or the Administration	Being part of a team Carrying out the activity Preparing the report
Exchange and mobility programmes	Erasmus-Socrates, Seneca programmes Final-year project in another country
Different academic activities	Lectures Symposia Different courses

Main competences (in addition to specific contents)
To be results-orientated. Obtaining of applicable results
Dealing with individual responsibility and environmental pressure due to restrictions in time, resources the pace of work
Responsibility and professional ethics. Social consequences of the activities
Coming to terms with the values of hierarchised work
Industrial documentation, the regulatory system, legislation
Languages
The sense of reality and economy in processes
Creativity
Multidisciplinary teamwork
Knowledge of the realities of industry and the professional world Time management
Oral, written and visual communication
Becoming aware of the international perspective
Languages
Understanding of other cultures and lifestyles
Becoming aware of the realities of other extra-academic activities
Cultural promotion

Learning strategies	The student’s activity
The use of programmes for self-learning and supervised on-line work	Solving tests and set problems Use of standard software
Tutoring Learning dossier	Compiling information
Final-year project/dissertation	Understanding the scope of the project Search for information Developing a specific piece of work Drawing up and presenting the results Possible collaboration with students in other specialities If carried out in a group: ■ Distributing the work among the group members ■ Summarising individual pieces of work

Main competences (in addition to specific contents)
Autonomy and management of one's own time
Responsibility for one's own learning
On-line documentation techniques
On-line teamwork
Self-criticism
Orderliness and systematisation
Self-esteem
Medium to long-term planning
Life-long Learning (L3)
Individual responsibility
Direct personal relationship with the director
This activity may include most of the competences obtained in other activities, depending on the type of final-year project that is undertaken

The number of ECTS credits as a whole in the programme need to be distributed between courses in proportion to the effort required of the student. The detailed planning of the courses needs to be done as a whole in this methodology, especially regarding approval of the activities to be undertaken. Individual initiative by teaching staff has a different meaning in this system to a less coordinated one, although it should not be ruled out because of this. Encouragement is needed to promote new contents, new activities and new evaluation procedures in line with the mechanisms for innovating teaching established by each university, but always with the necessary coordination of all activities proposed to the student.

Several of these strategies and activities are commented on below:

- **Master classes** are a classic tool that needs to be maintained but with fewer of them and with more structure, with the required information being supplied on paper or on-line. They are an efficient method of transmitting basic ideas, discussing concepts and supplying the structure of subjects. **Problem-based learning** has always been an indisputable learning strategy in chemical engineering. **Problem-solving in groups**, which are organised beforehand, may replace a considerable proportion of the master classes with greater effectiveness in learning. Work on real present-day, and therefore open, problems right from the first courses can help the meaning of engineering to be developed progressively, adapted to the knowledge acquired at each level, and in a motivating and inspiring way.

- **Laboratory work**, in its dual facets of learning basic techniques and the setting and experimental solving of open, more complex problems that require experiments, is an important aspect of learning but costly in terms of time, teaching staff and material resources. For this reason, the objectives of lab work need to be thoroughly considered prior to it being designed, the purpose being to be as selective and effective as possible. Laboratory work should not be about displaying phenomena explained in master classes, or the place to learn about data processing, but the place and time where experimental data are collected for a particular design or for learning how to handle certain equipment or procedures. One optimum option at advanced levels of learning is to have an **integrated laboratory**, with different kinds of equipment that enables various sequences of operations involving separation, conditioning and reaction to be carried out in order to obtain a product from raw materials or to process an effluent.

- It is highly advisable to draw up a **good practices manual** for each learning strategy, and there are various ways of doing this. For example, in the case of laboratory equipment, **standard work practices** in both operating equipment and waste management or safety in the laboratory. The good practices manual has the advantage of facilitating the organisation of activities by different teachers, permitting the monitoring and upholding of the faculty or department's style and way of working, and facilitating the work of evaluating a strategy's effectiveness.

- **Tutoring** is an essential tool in the ECTS system and the proposed design. Both academic tutoring on a specific subject that the teacher in charge undertakes with the students and transversal tutoring involving monitoring throughout a student's studies acquire a much greater significant importance than in previous models. Given that it is ultimately a question of accrediting competences, the student's knowledge, his/her personal progress in a subject and as a whole, it is essential that tutoring be continuously orientated from prior to initial registration to after the student has received the final credit. It is not a question of controlling the final quality at the end of the whole process but really of assuring the quality of each activity at each point in the process and of constantly measuring the student's progress so that he/she assumes the responsibility for his/her own training process, under the tutelage and guidance of the tutor. Tools such as the personal **learning file**, **time management** and other similar techniques must form part of the programme specification, because they make a notable contribution to verifying a student's progress, which significantly increases his/her self-esteem and helps him/her to design his/her own future in accordance with personal capabilities and expectations.

- The **final-year project** or **final-year dissertation** is one of the classic strategies for training engineers that is absolutely consolidated and will be continued in the future for both pedagogical and legal reasons. There are many varied ways that this can be undertaken: individually or as part of a group, at the student's proposal or designated by teaching staff, associated with research work being developed at the faculty or a plant design, or by carrying out an industrial job in private enterprise. In any event, and with respect to all types and styles, the characteristic they all have in common is the need for the project to be of a professional level and real, in terms of the approach, development, way it is carried out and presentation. The training acquired in this activity may include a variety of subject specific and transversal competences, and it should be one of the crowning moments in the student's formative process. Specific protocols and standards of good practice should be developed for this to be carried out as rigorously and demanding as possible.

- **Evaluation** forms part of the training process and is therefore a constituent part of the design of the programme specification. Evaluation systems are as varied as training activities. As with training activities, evaluation needs to be programmed as a whole. Every training activity has to be evaluated, either individually or comprehensively, and this is an area in which a lot of innovation can be developed. Oral evaluations at different times during the studies (expositions, presentation of reports, the viva voce or final-year project) improve oral communication, which is one of the usual shortcomings of the student body. **Peer evaluation** (between students) is a technique that, well applied, is useful not just for evaluation purposes but also for the student's training in that it gives him/her a critical sense, independence of criterion, discernment and a sense of justice, responsibility and professional ethics.

- Consistent with the ultimate objectives of the programme specification, one should remember that it is a question of ensuring that graduates of the programme specification obtain the competences that they have trained in. It is therefore essential to develop not just systems to evaluate contents and skills but also reliable mechanisms for generic, subject specific and transversal **competence accreditation**. Classic evaluation systems only do this to a small degree because they were designed mainly to measure the success of content transmission. Moreover, evaluation strategies based exclusively on traditional methodologies (final exams) are not compatible with most of the methodologies proposed in this document, and appropriate mechanisms for **continuous evaluation** need to be developed.

Cuadro 10. Competences and assessment strategies

Transversal competences	Tests capable of measuring them
Knowledge of the discipline	Objective tests, open questions, problem-solving
Competences specific to the discipline	Evaluation of products (posters, opinions, reports), evaluation of performance (assessment forms, laboratory, work experience/placement, etc.), research projects
Critical thinking	Research projects, case studies, simulations, learning dossiers, laboratory assessment
Problem-solving	Collection of problems, group work, thesis/project, laboratory assessment
Expression through writing	Course work, learning dossiers (essays), research reports, laboratory notebook
Oral communication	Presentations, debates, simulated interviews, answers/questions in the laboratory
Teamwork	Group work, peer evaluation, self-evaluation
Documentation and sources	Bibliographical work, research projects, case studies
Ethical reasoning and values	Indirectly either by means of performance (final-year project, placement/internship, case studies, etc.), or more directly through the use of qualitative measuring instruments (debates, interviews, focus groups with students, etc.) or quantitative ones (scales of attitudes, surveys)
Life-long learning	Self-evaluation, evaluation of classmates, learning dossiers
Initiative	Performance evaluation, self-evaluation, work experience/placement in private enterprise

Source: Prades, 2005

- The drawing up of **curricula** for the programme, subject and course is the putting into practice of the above-mentioned ideas. Details of the general and subject specific objectives, the teaching strategies and activities to be carried out, plus a detailed evaluation of the activities, are given in each course syllabus, according to how each university and faculty decides. Each syllabus is thus the commitment or contract between the student, the faculty and each teacher involved in teaching. By means of this commitment, the faculty undertakes to supply the students with the necessary material, intellectual and human resources for them to develop the competences described in the profile, the student undertakes to put his/her energy and time into studying in accordance with the proposed plan, and the teacher undertakes to participate in the part assigned to him/her to ensure the success of the project in common, in relation to the specifying, teaching and evaluating of subjects that he/she is entrusted with, as well as more transversal activities, such as adapting the design of the programme specification, overall evaluation and tutoring the students.
- Some competences that must be attained are acquired diffusely in multiple activities and by one's mere presence in the institution. Tidiness, respect for people and things, punctuality, orderliness, flexible communication and kindness, and a mind open to collaboration with others are values that must permeate the atmosphere of the institution at all times and in all activities. It is the responsibility of the faculty's managerial bodies and each member of staff to contribute to setting up and maintaining this atmosphere, which is a formative factor of the first order.

4.3. Design evaluation stage

The process of designing the programme specification, like any other project that is developed, has to be monitored by the particular quality assurance system used by the university and faculty. There are many quality assurance models and all may be appropriate.

All throughout the development of the study programme, mechanisms need to be established for it to be monitored and appropriate changes introduced when necessary. By means of interviews, group discussions with students, academic tutors, etc., it is necessary to analyse whether any overlapping occurs between subjects and courses, if the sequence is suitable (and, for example, if there are any difficulties due to lack of prior knowledge), if the academic level is appropriate (not too easy and not too difficult), etc. Within the context of ECTS, it is necessary to oversee particularly that the student's load and distribution of work are appropriate.

Evaluation of the design has to be made by an external committee from the faculty or university. With regard to this, special validation is required for the correct planning of the entire programme specification, and above all that the student's workload, together with the different types of activity throughout a course and from one course to the next, are well balanced.

Formal evaluation by an external committee is also very interesting, although it is probably more important for evaluating the results of the design, i.e. for evaluating graduates of the system once it has been put into practice. Systematic information is thereby periodically provided on the need for modifications to the programme specification and on new social needs, in a continuous process of improvement. This periodic external evaluation must also form part of the design process. The consulting of external groups is especially appropriate:

- Survey of the level of satisfaction of recent graduates.
- Survey of graduates five years after finishing their studies.
- Survey of employers on the performance, shortcomings and strong points of degree holders.
- Survey of Master's/PhD cycle teaching staff on graduates of the programme specification.

In the design stage, it is important to bear in mind the mechanisms for evaluation and accreditation that the study programme and degree will be submitted to. Examples are the documents from the quality evaluation agencies like ANECA and AQU Catalunya, for example *Estàndards d' acreditació de les proves pilot* (AQU Catalunya, 2005, Accreditation criteria for pilot tests). International systems of external accreditation are also of particular interest to programmes in engineering, such as accreditation by the ABET (Accreditation Board for Engineering and Technology) and the EFQM (European Foundation for Quality Management). An external accreditation process is costly in terms of human and economic resources, although it offers the advantage that guidelines for evaluation are already set by the system itself and this frees the institution from having to define its own.

International recognition of the quality of a programme gives great credibility and enhances the self-esteem of both the institution and its teachers, as well as urging it on towards permanent improvement and continuous monitoring to correct any malfunctioning that may appear over time. The programme's external image —in the eyes of the students and their families, as well as employers— benefits greatly as a result, and there is an increase in the prestige of graduates from the institution.

Annex 1
The letter to employers

Dear Sir,

Dear Madame,

As you are aware, the European university system is well into the process of setting up the European Higher Education Area (EHEA) to establish the situation where the mobility of students and graduates, as well as programme recognition and exchanges between participating states, is made easier.

One of the most notable developments in the new system is the establishing of two programme levels, the graduate (or Bachelor) and Master, which follows on from the Bachelor. Both levels are professionally orientated but at different levels and involving different competences. At the time when this letter was written, the Ministry had still to decide on the duration of programmes, which will vary from three to four years and one to two years, respectively.

The Agència per a la Qualitat del Sistema Universitari de Catalunya (AQU Catalunya, Quality Assurance Agency for the Catalan University System) is involved in the work of ensuring that the process of review and change in Catalonia is as rigorous and coordinated as possible. The Chemical Engineering programme is one of three that were chosen by AQU Catalunya to form part of the DISSENY programme, the objective of which is to systematically develop methods and procedures for preparing undergraduate degree curricula, based more on the requirements of demand than on the supply capacity of the system. One of the stages involves the consultation of significant persons in different categories and bodies who are directly or indirectly involved in hiring future graduates.

The purpose of this letter is to request your collaboration in completing the enclosed questionnaire. It was prepared by an AQU Catalunya working group, with representatives of all of the universities that currently have programmes either in Chemical Engineering (long cycle) or Industrial Engineering, with the specialisation in Industrial Chemistry (short cycle), namely UB, UAB, UPC, UdG, URV and URL.

You are asked to assess, from 1 to 4 (1: not at all relevant; 2: not very relevant; 3: very relevant; 4: highly relevant), the relevance or interest of the learning outcomes that a graduate (Bachelor) should obtain in each item. Please bear in mind that you are being asked to assess what would be desirable in a graduate entering the labour market for the first time and not the competences and abilities of either a practicing senior chemical engineer or those of a graduate with a Master's degree in a specialised subject.

A look at the survey will reveal that most of the elements to be evaluated are not training contents but the competences or capacities developed bu students. The DISSENY programme is based first on the specification of required abilities and competences, which are used to define the appropriate formative contents and methodologies for these to be attained.

Please add any appropriate comments to clarify points, and add new competences or abilities, where appropriate. If for whatever reason you consider it to be more suitable for someone else in your circle to complete the questionnaire, please feel free to do so. I would also be grateful, in case it is not appropriate or if you cannot fill out the questionnaire, if you could return it to the address above.

On behalf of the AQU Catalunya Director, Dr. Gemma Rauret, and the members of the working group, I thank you in advance for your collaboration.

Claudi Mans

Coordinator, DISSENY programme Chemical Engineering working group

Barcelona, 14 December 2004

Annex 2 Questionnaire

Scientific fundaments

Have the ability to use the following knowledge to analytically, numerically and visually establish and solve a variety of typical chemical engineering problems

Importance for the Bachelor

1. Not at all relevant
2. Not very relevant
3. Very relevant
4. Highly relevant

	1	2	3	4
1. Have relevant knowledge of the basic sciences and in particular mathematics — including statistics —, chemistry, biology, physics and economic principles, for understanding, describing and solving typical chemical engineering problems	☐	☐	☐	☐
2. Have sufficient knowledge and criteria about organic chemistry, inorganic chemistry and physical chemistry, biochemistry and materials science	☐	☐	☐	☐
3. Understand the principles on which modern methods of chemical analysis are based, their limitations and applicability to chemical processes	☐	☐	☐	☐

Importance for the Bachelor

1. Not at all relevant
2. Not very relevant
3. Very relevant
4. Highly relevant

	1	2	3	4
Understand the basic principles underlying chemical engineering:				
4. Balances of matter, energy and motion	☐	☐	☐	☐
5. Thermodynamics, between-stage equilibrium and chemical equilibrium	☐	☐	☐	☐
6. Kinetics of the physical processes of mass, energy and motion transfer, and chemical kinetics	☐	☐	☐	☐
7. Others: which?	☐	☐	☐	☐
8. Others: which?	☐	☐	☐	☐
9. Others: which?	☐	☐	☐	☐

Skills in the discipline

	Importance for the Bachelor: 1. Not at all relevant	2. Not very relevant	3. Very relevant	4. Highly relevant
	1	2	3	4
1. Know the different reaction, separation, transport and circulation processes of fluids and materials processing involved in industrial processes of chemical engineering	☐	☐	☐	☐
2. Understand the main concepts of process control in chemical engineering	☐	☐	☐	☐
3. Have the ability to analyse complex problems in the field of chemical engineering	☐	☐	☐	☐
4. Interpret experimental situations and actions	☐	☐	☐	☐
5. Plan, carry out and explain experiments in the different areas of chemical engineering, and know how to communicate them	☐	☐	☐	☐
6. Have knowledge of the scientific and technical bibliography and sources of relevant data	☐	☐	☐	☐
7. Have the ability to design chemical engineering processes, equipment and installations	☐	☐	☐	☐
8. Be capable of judging the economic viability of a chemical engineering industrial project	☐	☐	☐	☐
9. Have appropriate knowledge of relevant guidelines, legislation and regulations in all situations	☐	☐	☐	☐
10. Experience with the use of appropriate generic and specific software for chemical engineering	☐	☐	☐	☐

Importance for the Bachelor

4. Highly relevant
3. Very relevant
2. Not very relevant
1. Not at all relevant

	1	2	3	4
11. Understand the central role of chemical engineering in preventing and solving environmental and energy problems, in line with the principles of sustainable development	☐	☐	☐	☐
12. Assess, in a structured and systematic way, the hazards for safety, health and hygiene in a process that either exists or is in the design stage, and apply relevant measures	☐	☐	☐	☐
13. Be capable of understanding the impact of engineering solutions on the environmental context and general social context	☐	☐	☐	☐
14. Have assumed the values of responsibility and professional ethics that are characteristic of chemical engineering	☐	☐	☐	☐
15. Have the capacity to use the knowledge above-mentioned competences to prepare a chemical engineering project	☐	☐	☐	☐
16. Others: which?	☐	☐	☐	☐
17. Others: which?				
18. Others: which?	☐	☐	☐	☐

General transversal competences

Importance for the Bachelor

4. Highly relevant
3. Very relevant
2. Not very relevant
1. Not at all relevant

Personal competences	1	2	3	4
1. Be independent, dynamic and organised, and capable of analysis and synthesis, critical analysis and long-term planning	☐	☐	☐	☐
2. Have a high self-esteem and frustration tolerance	☐	☐	☐	☐
3. Be results-orientated, with the ability to solve problems in the absence of evidence, creative, and capable of initiative and decision-making and handling information	☐	☐	☐	☐
4. Have the capacity for self-assessment and constructive self-criticism	☐	☐	☐	☐
5. Be capable of learning on one's own. Recognise the need for life-long learning and possess an active attitude to do so	☐	☐	☐	☐
6. Others: which?	☐	☐	☐	☐

Competences in communication	1	2	3	4
1. Ability to communicate effectively, clearly and concisely, orally and in writing, using presentations with appropriate support materials	☐	☐	☐	☐
2. Be acceptably fluent in English to communicate and relate socially, and knowledge of another relevant world language	☐	☐	☐	☐
3. Others: which?	☐	☐	☐	☐

Importance for the Bachelor

1. Not at all relevant
2. Not very relevant
3. Very relevant
4. Highly relevant

Interpersonal competences	1	2	3	4
1. Capable of team work and adapting to multidisciplinary and international teams on different scales	☐	☐	☐	☐
2. Have leadership and negotiating abilities, be capable of using relevant activating resources to direct and lead working groups, motivate collaborators, generate empathy and negotiate	☐	☐	☐	☐
3. Willingness to accept corporate culture	☐	☐	☐	☐
4. Others: which?	☐	☐	☐	☐

Annex 3
Results of the consultation of employers and graduates on the programme specification for Chemical Engineering

Results of the consultation of employers and graduates on the programme specification for Chemical Engineering

Scientific fundaments

Have relevant knowledge of the basic sciences, in particular mathematics, chemistry, biology, physics and the principles of economics, in order to understand, describe and solve typical chemical engineering problems

Have sufficient knowledge and criteria of organic chemistry, inorganic chemistry and physical chemistry, biochemistry and materials science

Understand the principles on which modern methods of chemical analysis are based on, their limitations and applicability to chemical processes

Understand the basic underlying principles in chemical engineering: material balance, energy and quantity of motion

Understand the basic underlying principles in chemical engineering: thermodynamics and between-stage equilibrium and chemical equilibrium equations

Understand the basic underlying principles in chemical engineering: kinetic equations of physical transfer processes (mass, energy and quantity of motion) and chemical reaction kinetics

Skills in the discipline

Know the different reaction, separation, transport and circulation processes of fluids and materials processing involved in industrial processes of chemical engineering

Understand the main concepts of process control in chemical engineering

Have the ability to analyse complex problems in the field of chemical engineering

Interpret experimental situations and actions

Plan, carry out and explain experiments in the different areas of chemical engineering, and know how to inform about them

Have knowledge of the scientific and technical bibliography and sources of relevant data

Have the ability to design chemical engineering processes, equipment and installations

TEACHING STAFF			EMPLOYERS			GRADUATES		
N	Mean	Stan. dev.	N	Mean	Stan. dev.	N	Mean	Stan. dev.
94	3.70	0.48	23	3.39	0.78	47	3.64	0.53
93	3.28	0.71	23	3.13	0.81	48	3.13	0.73
93	2.80	0.73	23	2.61	0.78	48	3.08	0.71
93	3.87	0.40	23	3.39	0.84	48	3.52	0.68
93	3.77	0.45	23	3.13	0.92	48	3.23	0.66
93	3.67	0.56	23	3.22	0.80	48	3.17	0.72
92	3.62	0.51	23	3.26	0.81	44	3.52	0.70
92	3.36	0.62	23	3.30	0.56	44	3.30	0.79
92	3.26	0.68	23	3.22	0,80	44	3.11	0.69
92	3.37	0.67	23	3.35	0.65	44	3.59	0.54
91	3.09	0.72	23	3.26	0.75	43	3.12	0.70
93	3.12	0.69	22	2.95	0.79	43	3.02	0.74
93	3.25	0.76	23	3.04	0.77	43	3.26	0.88

Be capable of judging the economic viability of an industrial chemical engineering project

Have appropriate knowledge of legislation and regulations in all situations

Experience with the use of appropriate generic and specific software for chemical engineering

Understand the central role of chemical engineering in preventing and solving environmental and energy problems, in line with the principles of sustainable development

Assess, in a structured and systematic way, the hazards for safety, health and hygiene in a process that either exists or is in the design stage, and apply relevant measures

Be capable of understanding the impact of engineering solutions on the environmental context and general social context

Have assumed the values of responsibility and professional ethics that are characteristic of chemical engineering

Have the capacity to use the knowledge above-mentioned competences to prepare a chemical engineering project

Transversal competences

Be independent, dynamic and organised, and capable of analysis and synthesis, critical analysis and long-term planning

Have a high self-esteem and frustration tolerance

Be results-orientated, with the ability to solve problems in the absence of evidence, creative, and capable of initiative and decision-making and handling information

Have the capacity for self-assessment and constructive self-criticism

Be capable of learning on one’s own. Recognise the need for life-long learning and possess an active attitude to do so

Ability to communicate effectively, clearly and concisely, orally and in writing, using presentations with appropriate support materials

Be acceptably fluent in English to communicate and relate socially, and knowledge of another relevant world language

TEACHING STAFF			EMPLOYERS			GRADUATES		
N	Mean	Stan. dev.	N	Mean	Stan. dev.	N	Mean	Stan. dev.
92	3.08	0.77	23	3.00	0.67	44	3.41	0.73
93	2.65	0.76	23	3.00	0.67	44	3.00	0.89
93	3.10	0.63	23	3.04	0.77	44	3.32	0.71
93	3.24	0.65	23	3.17	0.72	44	3.23	0.77
92	3.40	0.59	23	3.57	0.59	44	3.32	0.71
91	3.11	0.66	23	3.22	0.67	44	3.16	0.81
93	3.39	0.64	22	3.36	0.73	44	3.14	0.85
93	3.31	0.69	23	3.26	0.62	44	3.48	0.76
94	3.52	0.56	23	3.57	0.51	48	3.69	0.55
94	3.06	0.67	23	2.96	0.64	48	3.29	0.77
93	3.35	0.69	23	3.35	0.65	48	3.60	0.68
94	3.27	0.61	23	3.17	0.78	48	3.50	0.58
94	3.53	0.62	23	3.48	0.67	48	3.63	0.53
94	3.47	0.62	23	3.43	0.66	48	3.33	0.69
94	3.48	0.52	23	3.48	0.67	48	3.40	0.74

Capable of team work and adapting to multidisciplinary and international teams on different scales
Have leadership and negotiating abilities, be capable of using relevant activating resources to direct and and lead working groups, motivate collaboraters, generate empathy and negotiate
Willingness to accept corporate culture

TEACHING STAFF			EMPLOYERS			GRADUATES		
N	Mean	Stan. dev.	N	Mean	Stan. dev.	N	Mean	Stan. dev.
92	3.62	0.51	23	3.83	0.39	48	3.63	0.64
94	2.89	0.73	23	3.09	0.67	48	2.90	0.78
92	2.98	0.80	23	2.96	0.64	48	2.88	0.70

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