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EUR-ACE accreditation for chemical engineering in Spain: Current situation, lessons learned and challenges

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ABSTRACT

The accreditation of engineering programmes is a subject of great interest in the last decades. However, most studies in the literature are focused on case studies or deal with the different levels of acceptance of the groups involved in the accreditation. There are two main approaches for the accreditation of engineering programmes, i.e., at national or international level. Whereas most developed countries have established national standards for the quality assurance of the university studies, international accreditation systems for engineering studies are limited to 3 alternatives. The interaction between national and international accreditation systems is poorly understood despite of their significance in the design and management of the programme. We aim to fill in this gap and provide useful guidance for universities aiming to apply for the EUR-ACE® label in their chemical engineering programmes (bachelor or master). In general, there is a high level of complementarity between the Spanish and EUR-ACE accreditation systems. However, there are still challenges. For instance, the ad hoc procedure proposed by the national accreditation agency in Spain does not fully consider chemical engineering as a traditional branch of engineering. In addition, the changes in the Spanish accreditation system might negatively impact the current ad hoc procedure for EUR-ACE accreditation for some universities. The incorporation of IChemE in the accreditation process would be an option to deal with this issue.

1. Introduction

1.1. Accreditation systems and Chemical Engineering

Accreditation has become a major preoccupation worldwide and several countries have or are adopting accreditation frameworks to get global recognition of their engineering programmes (Aoudia, 2022). This has become a strategy for technical universities and generalist universities with technical programmes. However, it is crucial a positive attitude of the teaching staff and students towards the accreditation programme (Jurvelin et al. 2018, Niemelä et al. 2014) considering the changes in teaching methodologies, evaluation systems and quality management.

Nowadays, there are three main international accreditation systems for engineering studies: ABET (Accreditation Board for Engineering and Technology), CDIO (Conceive-Design-Implement-Operate Real World) and EUR-ACE. de Azevedo (2009) provided a thorough comparison of them, being their most relevant characteristic that they are applicable to a wide range of engineering studies.

The accreditation of chemical engineering programmes shares a great similarity with other engineering studies, benefiting of a common framework. Like other traditional branches of engineering, there is an additional accreditation system with international recognition tailored to chemical engineering programmes, i.e., the IChemE accreditation, managed by the Institution of Chemical Engineers (UK) (IChemE).

1.2. The EUR-ACE® label

The European Network for Accreditation of Engineering Education (ENAEE) defines EUR-ACE® as the European quality label for engineering degree programmes at Bachelor and Master Level (ENAEE, 2023). The EUR-ACE® label is widely implemented in Europe, where there are 558 accredited programmes in at least 9 countries. In 2007, the first degrees were awarded with the EUR-ACE® label and in 2014 the

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EUR-ACE® Accord was signed by the 13 associated accreditation agencies, whereby accepting each other's accreditation decisions in respect of bachelor's and master's degree programmes (ENAEE).

The EUR-ACE® accreditation process is in line with the European Qualifications Framework (EQF, 2023), which in practice implies that only bachelor's degrees from 3 to 4 years, as well as master's degrees from 1 to 2 years are eligible.[1] In addition, the EUR-ACE Framework Standards can be assimilated to a "sectoral framework": i.e., they are valid for all "branches" of engineering and for all educational "profiles" (either more theoretically or more vocationally oriented) (Augusti, 2011). Therefore, EUR-ACE does not specifically consider chemical or any other engineering discipline.

In brief, the accreditation process evaluates two different aspects:

1. The management of the programme (Bachelor/Master), which should be consistent with the standards of the European Higher Education Area. In particular, the following aspects are covered:
   11. Programme Aims
   12. Teaching and Learning Process
   13. Resources
   14. Student admission, transfer, progression and graduation
   15. Internal Quality Assurance
2. The learning outcomes of the programme[2] (Bachelor/Master), which should enable graduates to demonstrate a certain level of knowledge, understanding, skills and abilities (see Boxes 1 and 2 in the Appendix). The programme outcomes are grouped into eight learning areas:
   21. Knowledge and understanding
   22. Engineering Analysis
   23. Engineering Design
   24. Investigations
   25. Engineering Practice
   26. Making Judgements
   27. Communication and Team-working
   28. Lifelong Learning

The direct accreditation of engineering programmes is not carried out by ENAEE. However, a set of associated accreditation agencies accredit the programmes. These agencies should follow a specific procedure defined by ENAEE. At present, 14 national agencies are allowed to award the EUR-ACE® label (ENAEE).

1.3. Status of the EUR-ACE® label in Spain

Globally, over 170 chemical engineering degree programmes at First Cycle (Bachelor), Second Cycle (Master) and Integrated Second Cycle (Master) are currently awarded the EUR-ACE® label by ENAEE Authorized Agencies (ENAEE). In Spain, for the academic year 2022/23 (RUCT, 2023), 28 out of 60 chemical engineering degree programmes are awarded this label: 22 out of 40 (55%) bachelor's degrees and 6 out of 20 (30%) master's degrees. The Universidad de Sevilla (*University of Seville*) is the third university in number of EUR-ACE accredited engineering programmes in Spain (Bonilla-Calero et al. 2022).

1.4. Novelty and aims of the study

Augusti (2006, 2007, 2009) was the first to discuss the challenges and opportunities of the implementation of the EUR-ACE accreditation programme. Later studies focused on the impact of accreditation in specific courses (e.g., electronics) or studies at national level (Carrillo et al., 2016, Duarte and Costa (2015)). Studies focused on accreditation for chemical engineering programmes are scarce (Gani, 2011, Bolton et al. 2023, Byrne, 2023, Mitchell, 2000), some of them considering accreditation as part of a broader analysis (Wankat, 2013, Campbell and Belton (2016), Brown et al. 2019). Previous studies on the chemical engineering programmes in Spain only focused on describing their situation and providing useful indicators of the incoming students, as well as the professional outcome of the chemical engineers (Feijoo et al. 2018, López-Pérez et al. 2023). Nevertheless, no previous study has analysed the procedure for EUR-ACE accreditation in Spain.

In this study, we aim to provide a guide for the accreditation of the EUR-ACE® label in Spain, focusing on the practical issues that universities have to address, considering the national accreditation system and the peculiarities of the chemical engineering teaching in Spain. We include a list of the lessons learnt in the EUR-ACE accreditation process, the challenges for the future, as well as some recommendations. The conclusions of the study may be also of help for universities in other European countries.

2. The Spanish accreditation framework

2.1. Overview of the mandatory accreditation system

The Spanish accreditation framework is defined by a national regulation (RD 822/21) and it is focused on assessing the fulfilment of the standards of the European Higher Education Area in bachelor, master and doctoral studies (RD 822/21, 2021). This regulation gives a large degree of autonomy to the regions (*Comunidades Autónomas*) in the supervision of the bachelor's and master's degrees. Therefore, most of the regions have enacted their own accreditation agencies. Nonetheless, there is still a national accreditation agency (Spanish National Agency for Quality Assessment and Accreditation: ANECA) that supervises the studies in the regions that do not have a regional agency. All accreditation agencies are associated to the Spanish Network of Quality Assurance in the University (REACU), which fosters collaboration among the agencies and contributes to the establishment of common benchmarks for the accreditation of university studies in Spain.

The accreditation process is based on the submission of individual reports per programme to the regional accreditation agencies or ANECA by the universities. Evaluation panels are nominated by the agencies and formed by two academic representatives and one representative of students, none of them from the region of the university under evaluation. There is a meeting (online or in-person) where the panel interviews the academic personnel and board of programme, students and graduates, and representatives of the employers of the graduated students. After the visit, a report is prepared with a decision on the accreditation of the programme. This decision can be accepted without reservation, accepted with prescriptions/conditions, or denied. The accreditation must be renewed every six years for all degrees.

Nowadays, the system is rapidly moving from the accreditation of individual degrees to the accreditation of university centres (*acreditación institucional*). The progress is very uneven through the regions in Spain. From conversations of the main author with quality assurances vice-deans of different Spanish universities, the main reasons are delays in the adaptation of the internal procedures in some regional agencies, lack of confidence in the permanency of the regulation ("better to sit and wait if this is going to work"), and resistance to change by staff, are the most relevant issues.

2.2. Compatibility with the EUR-ACE accreditation system

Spanish bachelor's degrees in engineering are 4-years degrees, whereas the master's degrees in engineering range from 1 to 2 years.

Most of the regions in Spain have accredited their degrees with

[1] It is possible to accredit integrated master programmes, i.e., a programme combining a master's and a bachelor's degree, if they are above 4 years (ENAEE).

[2] As it is defined by ENAEE, learning outcomes are used to describe the knowledge, understanding, skills and abilities which apply to individual course units/modules.

ANECA (the national accreditation agency). Although there is a common framework defined at national level (RD 822/21), there is an impact on the EUR-ACE accreditation system. Since the EUR-ACE accreditation in Spain can only be processed by ANECA, there has been a sort of conflict in the role of the regional agencies in the process, as they are the only competent to assess the consistency of the management of the programme with the standards of the European Higher Education Area (aspects 1.1–1.5).

There is an option for universities to follow the accreditation process by organizations different than ANECA. Such is the example of universities in Catalonia, where ASIIN acts as accreditation agency. However, the role of the regional accreditation agency is still important in the definition of the aspects 1.1–1.5.

Finally, there is an option to apply for the EUR-ACE® label through the Engineering Council (regulatory body for the UK engineering profession). This option requires a prior IChemE accreditation. To the best of our knowledge, none of the Spanish universities with the IChemE accreditation (i.e., Universidad de Oviedo, Universidad de Santiago de Compostela) has used this option so far.

3. The role of ANECA as EUR-ACE accreditation agency in Spain

3.1. Structure and basic information

ANECA, as one of the associated accreditation agencies to ENAEE, has developed an ad hoc procedure for the EUR-ACE accreditation of bachelor's and master's degrees (see Fig. 1). ANECA signed an agreement with the *Instituto de la Ingeniería de España* (IIE), in which ANECA supervises the accreditation process and IIE provides experts for the evaluation panel. The IIE is a registered charity in Spain, funded in 1905, that advances the contribution to society of the most traditional branches of engineering in Spain (i.e., aerospace, agricultural, civil, forestry, mining, naval, plant and telecommunications engineering) (IIE, 2023).

Universities willing to apply for the EUR-ACE evaluation of their engineering programmes should have accredited their programmes according to the Spanish accreditation framework not later than 2 years before the application. For the EUR-ACE application, universities should submit the final report from the Spanish accreditation to ANECA, which will certify that the management of the programme is consistent with the standards of the European Higher Education Area (aspects 1.1–1.5). In addition, a report explaining how the programme achieves the learning outcomes of EUR-ACE® label is submitted. This second report should include additional information that is not explicitly covered in the first report (Spanish accreditation), i.e., the institutional support of the university to the engineering programme in terms of resources and internal quality assurance considering the particularities of engineering studies. There is a single annual application period for the EUR-ACE® label.

ANECA and IIE nominate a panel for the evaluation of the programme, which typically will evaluate up to 4 different programmes in the same university. The panel's composition is similar to the Spanish accreditation (i.e., two academic representatives and one representative of students), but also a representative of the profession (i.e., an engineer) is incorporated to judge the achievement of the learning outcomes. After an initial review of the two reports (outcome from the Spanish accreditation; and the learning outcomes of EUR-ACE® label), there is a meeting (online or in-person) where the panel interviews the academic personnel and board of programme, students, recent graduates, and representatives of the employers of the graduated students.

There are three possible outcomes of the EUR-ACE accreditation. If the engineering programme meets all learning outcomes (see Boxes 1 and 2 in the Appendix) to a (very) satisfactory degree, the EUR-ACE® label is awarded for a period of 6 years, including also graduates that graduated the same year of the application. If the programme fails to meet up to 6 learning outcomes, then the EUR-ACE® label is awarded for a period of 3 years, including also graduates that graduated the same year of the application. In such a case, an action plan would be required to address the failing outcomes with specific measures that will be evaluated after the 3 years. A positive evaluation of these measure, meaning that all learning outcomes are met, will extend the EUR-ACE® label for another 3 year (up to a total of 6 years). Finally, if more than 6 learning outcomes are not met, the label is not awarded (in addition, early re-submissions are firmly discouraged). The learning outcomes that are most often not fully met (60%) are from the following learning areas: engineering design, engineering practice, and communication and team-working (Bonilla et al., 2022).

3.2. Overview of the studies of chemical engineering in Spain

As it has been mentioned before, in EUR-ACE accreditation chemical engineering is not specifically considered. This situation is aggravated in Spain, as the organization in charge of the accreditation, the IIE, does not include chemical engineering in their list of "classical engineering" studies.

The performance compared to the rest of the engineering degrees (number of labels secured) is way above the average. 25 out of 234 EUR-ACE® labels awarded until 2022 were within the chemical engineering discipline (Bonilla et al., 2022).

The teaching of chemical engineering in Spain is somehow different than in other European countries. Although degrees in chemical engineering were granted in Spain as early as in 1857 (Cano Pavón, 1996), it was not until the beginning of the 20th century when the modern chemical engineering appeared (inspired in the so-called "Course X", the first chemical engineering curriculum in the USA, introduced by the MIT

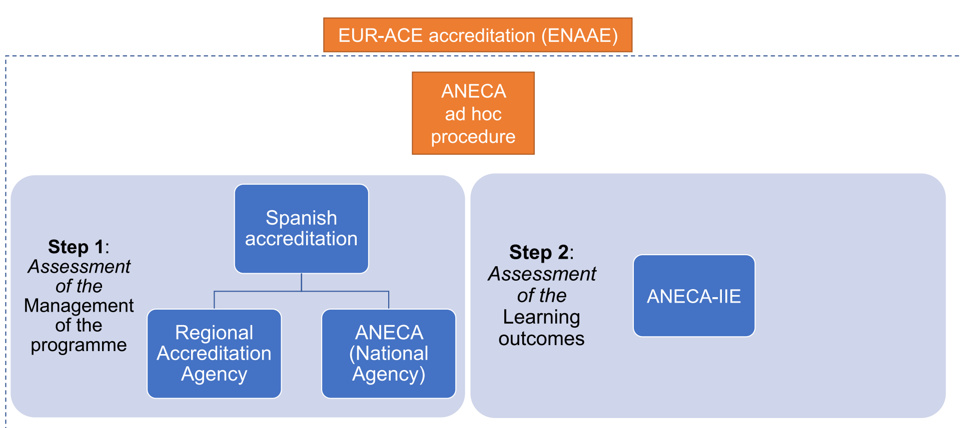

Fig. 1. Overview of the ANECA ad hoc procedure for EUR-ACE accreditation.

in 1888 and proposed by Prof. Lewis M. Norton (Kim, 2002)). However, chemical engineers were graduated as a specialization of a more general kind of engineering degree named *Ingeniero Industrial*: plant engineers (general engineers for industry). This specialization was equivalent to a major and covered all aspects defining a chemical engineer. Following 1970, Technical Schools of Engineering were created adapting existing vocational education in the industrial sector into engineering diplomas (including chemical engineering). Around the same time, Faculties of Sciences started to include a specialization of technical chemistry in their degrees of chemistry.

Therefore, in Spain, chemical engineering degrees are taught in three types of centres. They resulted from the adaptation of related former degrees in those centres to the national directive that regulates the studies of chemical engineering degrees (CIN/351/2009) (CIN/351/, 2009).

- Degrees related to Faculties of Sciences. Most Faculties of Sciences incorporated the studies of chemical engineering in the early 90 s. These Faculties had prior specializations in technical chemistry in their chemistry degrees, which were transformed into engineering degrees (bachelor and master). They have mostly kept teaching these degrees at the same Faculties of Sciences.
- Degrees related to former Technical Schools of Engineering. These Schools were similar to the German *Fachhochschule*, granting only diplomas in engineering. Traditionally, they had industrial chemistry degrees that have now evolved into chemical engineering bachelor's degrees. Today, a significant fraction of these degrees is linked to those taught at Faculties of Sciences (e.g., same departments for chemical engineering).
- Degrees related to historical Higher Technical Schools of Engineering. These Schools granted long-cycle (5 years) degrees in engineering. In particular, there was a degree for plant engineers (general engineers for the industry) equivalent to chemical engineering (i.e., *Ingeniero Industrial, Esp. Química*). In the late 90 s, the long-cycle engineering studies for plant engineers were adapted and the long-cycle for chemical engineering was established in these Schools that lately evolved into bachelor's and master's degrees in chemical engineering. Today, there is no link between these degrees and the Faculties of Sciences.

The number of degrees of chemical engineering related to historical Higher Technical Schools of Engineering is very limited (4 out of 40 for bachelor's degrees and 4 out of 20 for master's degrees).

3.3. The case of the ETSi

The Higher Technical School of Engineering of Seville, ETSi,[3] was founded in 1963 thanks to the sponsorship of the OECD, being one-of-a-kind at Spanish and international level (OCDE, 1968). The main aim for the establishment of a Higher Technical School of Engineering in Seville was to promote the industrialization of Andalusia, one of the most underdeveloped regions in Spain (OCDE, 1968). Since its creation, chemical engineers have graduated from the ETSi without interruption. Following the recommendations of the OECD[4] (OCDE, 1968), the ETSi has promoted multidisciplinary in the engineering studies along with a strong basis in engineering sciences (regardless engineering discipline or branch). An illustrative example would be that mechanical, electrical, or electronic engineers had course units on mass and energy balances as part of their programmes, while chemical engineers had course units on structural mechanics and fundamentals of civil engineering. This situation has slightly changed over time. Having this in mind, the ETSi is a well-reputed centre for engineering studies at national level that nowadays include aerospace, civil and telecommunication engineering, as well as the studies derived from the original plant engineers (general engineers for industry). In total, the ETSi has around 6000 students enroled in the different engineering disciplines and levels (bachelor, master, and doctorate).

Regarding the studies in chemical engineering, the bachelor's degree was established in 2010 and the master's degree in 2014. The current version of the master's degree has 90 ECTS, whereas the bachelor's degree has 240 ECTS. There is no option for a double bachelor's degree. However, there are two options offered to the students for a double master's degree with the Master in Environmental Engineering and the Master in Plant Engineering (*Ingeniería Industrial*). The number of chemical engineering students in the ETSi is reduced as a natural consequence of the large number of engineering degrees taught (i.e., chemical engineering students are only 8% of the student population in the ETSi).

3.3.1. Accreditation of the bachelor's degree in chemical engineering

The Bachelor's degree in Chemical Engineering at ETSi was originally designed to comply with the Spanish directive that regulates the studies that qualify for the profession of plant engineer specialized in the chemical industry (CIN/351/2009). The programme is in line with the standards of the European Higher Education Area and was accredited by the regional accreditation agency in Andalusia (ACCUA). The programme was originally designed without having in mind a future EUR-ACE accreditation. This complicated the EUR-ACE accreditation process, because for each learning outcomes required by EUR-ACE standards it was necessary to prove that there was a combination of the learning outcomes of the original programme that was equivalent. Evidence (assignments, exams, etc) for the realisation of the required learning outcomes were also requested. The accreditation process would have been easier if both the national legislation and the EUR-ACE standards had been considered in the original design of the programme. Fig. 2 shows the distribution of student workload for each learning area, where it is clear that knowledge and understanding is the most relevant area for bachelor's degrees. The panel recognized the quality of the courses that do not belong to the core of chemical engineering (e.g., circuit theory, automatic control, electronics, strength of materials, economics, management). As the ETSi has engineering degrees covering these disciplines, there is a mutual benefit between the departments involved in their teaching.

The bachelor's degree was finally awarded the EUR-ACE label for 3 years in April 2019 (3 learning outcomes were not fully met and some corrections to the programme management were required based on prescriptions from the national accreditation). The EUR-ACE label was extended for 3 years in April 2022 after the submission of an action plan that fully developed the failing 3 learning outcomes and improved the required programme management aspects.

3.3.2. Accreditation of the master's degree in chemical engineering

The Master in Chemical Engineering at ETSi was originally designed to comply with the Spanish resolution that regulates the studies that qualify for the profession of chemical engineer (BOE-A-2009–12977). In general terms, the accreditation process of the Master in Chemical Engineering to obtain the EUR-ACE® label was similar to that of the bachelor's degree (Section 3.3.1). The programme was also previously accredited by the regional accreditation agency in Andalusia (ACCUA). For each of the learning outcomes required for EUR-ACE® label, it was necessary to justify in what course unit(s) it was realised, how it was trained and assessed and provide evidence. Conversely to the accreditation of the bachelor's degree, where specific credits from each course were requested to justify the realisation of each learning outcome, for the master's degree, credits were no longer requested. In this case,

[3] The official name is *Escuela T é cnica Superior de Ingeniería de la Universidad de Sevilla* (ETSi).

[4] These recommendations along with the original syllabuses for all courses were collected in the so-called *yellow book* (OCDE, 1968). The recommendations for teaching methods included in the *yellow book* are still applicable today.

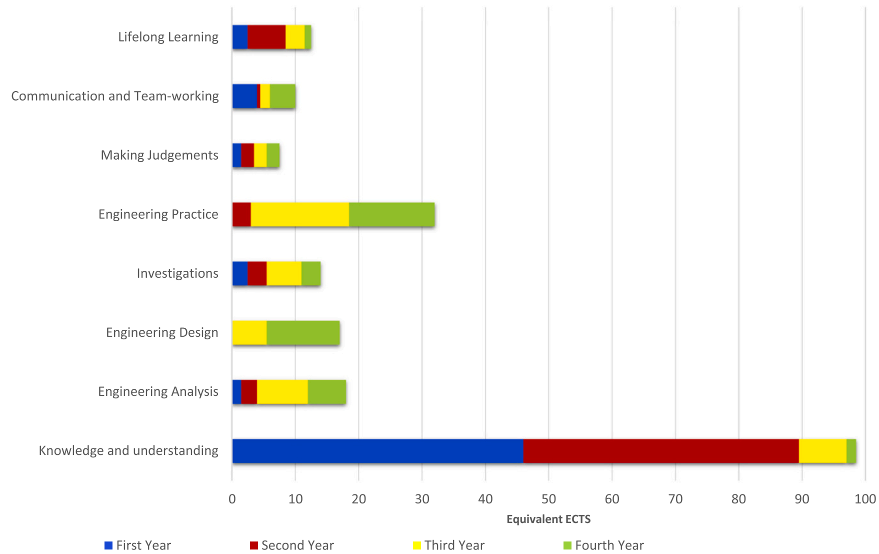

Fig. 2. Distribution of student workload (ECTS) to each programme outcome in the Bachelor's degree of Chemical Engineering at ETSi.

specific learning activities involved in the realisation of each outcome were only requested, as well as the perception of students and employers of the effectiveness of these activities. Table 1 shows the learning activities to realise the different learning outcomes in the programme. A difficulty for realising the learning outcomes compared to the bachelor's degree is the lower number of course units in the programme, which requires an intelligent design of the whole programme. Although the programme was not originally designed following the EUR-ACE standards and guidelines, it was smoothly modified along its first years to accommodate them based on the experience gained in the EUR-ACE accreditation of the bachelor's degree. Besides, the conceptual design of the master, where most of the course units involve student teamwork dealing with engineering problems, naturally allowed to fulfil the learning outcomes required for EUR-ACE label. On this regard, design of the course units to evaluate based on student teamwork was easier in the master's degree due to the lower number of students per class (25 against 60 for the bachelor's degree).

The master's degree was finally awarded the EUR-ACE label for 6 years in May 2023, as all learning outcomes were met.

3.4. Lessons learned and challenges

Chemical engineering programmes have performed outstandingly in their EUR-ACE accreditation, which shows the strength of these studies in Spain. The fact that these programmes were not originally designed considering the learning outcomes from EUR-ACE (or any other international accreditation systems) did not have an impact. However, most programmes will need to be revised in the next years according to a recent legal mandate (RD 822/21). Despite just been a minor update, it is an opportunity to fully integrate the learning outcomes into the curricula of the programmes. In addition, the neglecting of chemical engineering as a branch of engineering studies in the ANECA ad hoc procedure for EUR-ACE accreditation did not have an impact, either. However, the fact that professionals in the sector of chemical industry are not considered in the recruitment of representative of the profession for the evaluation panels is a negative sign of the quality of the ANECA ad hoc procedure.

An important drawback in the current ANECA ad hoc procedure is the accreditation of double degrees (bachelor or master), as well as integrated master programmes. In Spain, there are a few double bachelor's degrees combining chemical engineering and other engineering disciplines such as environmental engineering. In the case of double master's degrees, there are a few combining chemical engineering with environmental engineering or plant engineering (*Ingeniería Industrial*). In addition, Spain has recently incorporated the possibility of integrated master programmes in chemical engineering and some universities are offering this option since academic year 2022/23. However, the ANECA ad hoc procedure does not allow the EUR-ACE accreditation of these programmes, being forced to individual evaluation. Moreover, no recognition is provided (or expected) to the universities that have accredited both programmes, which is a lost opportunity in the promotion of such programmes.

The accreditation of university centres and not individual programmes might be a challenge for chemical engineering programmes in Spain. As most of the universities teaching chemical engineering do not link these studies with other engineering degrees, but with chemistry studies (i.e., they are taught in Faculties of Sciences and not in Schools of Engineering; see Section 3.2), the accreditation of the centre might not be valid within the EUR-ACE framework (management of the programme), as it is obvious that ENAAE distinguishes between Faculties of Sciences and Schools of Engineering.

Future challenges are derived from new possibilities in the definition of university studies according to the new national regulation (RD822/21). In particular, the possibility to incorporate the industrial sector in the academic programme (*mención dual*), meaning that a significant fraction of the courses will be taught outside the university (around 25–40% of the student workload). In addition, it is also possible to have a common learning itinerary for different engineering bachelor's degrees in the first and second academic years (*itinerario académico abierto*), meaning that the student will choose one of the bachelor's degrees only after passing the common itinerary. Finally, soft skills and the sustainable development goals are now to be mandatory incorporated into the programmes.

3.5. Recommendations

Considering the challenges from the previous section, we propose the following recommendations based on the experience of the ETSi in the accreditation of both the bachelor's and master's degrees in chemical engineering, as well as the analysis performed in this work.

Improved design of the programmes in chemical engineering (bachelor/master). Our recommendations are:

- To include the learning outcomes in the mandatory revision of all programmes in chemical engineering. This inclusion should

Table 1
Learning activities in the master's degree to realise the different learning outcomes in the programme.

Learning outcomes / Learning activities	Knowledge and Understanding	Engineering Analysis	Engineering Design	Investigation	Engineering Practice	Making Judgement Skills Communication and Team-working Skills	Lifelong Learning Skills
Lectures	***	**	*	**	***		*
Seminars	*	**	***	**	**	**	
Engineering Design Cases		***	***	*	**	**	***
Information search				***	*		**
Presentations						***	
Laboratory and computer classes				**			
Master's Thesis						***	

Level of intensity of each learning activity: high (***), moderate (**), low (*).

materialise in specific activities and their evaluation, and not only nominally.

- For the incorporation of the options of *mención dual* or *itinerario académico abierto* into the programmes, it is crucial to carefully consider the impact on the EUR-ACE accreditation. These options should be limited in any case only to other engineering programmes and preferably to programmes that are already accredited with the EUR-ACE® label.

Recognition of chemical engineering as a branch of engineering in the evaluation process for the EUR-ACE accreditation. Our recommendations are:

- To shift from the ad hoc procedure of ANECA to the IChemE accreditation. In this case, IChemE would firstly accredit the programme following their accreditation system and subsequent EUR-ACE accreditation through the UK Engineering Council. By doing so, it would be possible to have evaluation panels that are closely related to chemical engineering. This recommendation can be implemented without any further regulatory change and does not require any prior authorization by ANECA or the regional accreditation agency.
- A joint accreditation co-led by ANECA and IChemE.[5] In this case, a single evaluation process will be used for both the IChemE accreditation and EUR-ACE® label. In addition to the previous advantage related to evaluation panels, this approach seems more efficient in terms of time and compatibility with the Spanish accreditation system. However, the implementation of this recommendation requires an agreement of the accreditation agencies (ANECA, IChemE, but also the regional accreditation agencies, as they are responsible of the national accreditation and aspects 1.1–1.5 in EUR-ACE).

For those centres that are not mainly devoted to engineering studies (Faculties of Sciences). Our recommendations are:

- To carefully consider the accreditation of their centre (*acreditación institucional*), as the accreditation could not be aligned with EUR-ACE standards for the management of the programme. If that risk materializes, an option would be to opt out for the ANECA ad hoc procedure (see options above).

4. Conclusions

In this work, a practical guide for EUR-ACE accreditation of chemical engineering studies in Spain is presented along with the main challenges and recommendations. In general, there is a high level of complementarity between national and EUR-ACE accreditation systems, and programmes in chemical engineering have been very successful in their EUR-ACE accreditation. However, the ad hoc procedure followed by most universities in Spain does not fully consider chemical engineering as a traditional branch of engineering, being the most relevant impact that professionals of chemical engineering are not eligible as members of the for the evaluation panels. In addition, the changes in the national accreditation system might negatively impact the current ad hoc procedure for EUR-ACE accreditation. A set of recommendations is provided to face this and other issues derived from the new national regulation.

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[5] IChemE is open for joint accreditation and has previous experiences with Engineers Australia, UK Engineering Accreditation Board and Institution of Professional Engineers New Zealand (IChemE, 2023).

Appendix

Box 1
Programme outcomes for bachelor's degrees in EUR-ACE (extracted from ENAEE) organized by learning areas.

Learning area 1: Knowledge and Understanding
The learning process should enable **Bachelor Degree graduates to demonstrate:**

- knowledge and understanding of the mathematics, computing and other basic sciences underlying their engineering specialisation, at a level necessary to achieve the other programme outcomes;
- knowledge and understanding of engineering fundamentals underlying their specialisation, at a level necessary to achieve the other programme outcomes, including some awareness at their forefront;
- awareness of the wider multidisciplinary context of engineering.

Learning area 2: Engineering Analysis
The learning process should enable **Bachelor Degree graduates to demonstrate:**

- ability to analyse complex engineering products, processes and systems in their field of study; to select and apply relevant methods from established analytical, computational and experimental methods; to correctly interpret the outcomes of such analyses;
- ability to identify, formulate and solve engineering problems in their field of study; to select and apply relevant methods from established analytical, computational and experimental methods; to recognise the importance of non-technical –societal, health and safety, environmental, economic and industrial – constraints.

Learning area 3: Engineering Design
The learning process should enable **Bachelor Degree graduates to demonstrate:**

- ability to develop and design complex products (devices, artefacts, etc.), processes and systems in their field of study to meet established requirements, that can include an awareness of non-technical – societal, health and safety, environmental, economic and industrial– considerations; to select and apply relevant design methodologies;
- ability to design using an awareness of the forefront of their engineering specialisation.

Learning area 4: Investigations
The learning process should enable **Bachelor Degree graduates to demonstrate:**

- ability to conduct searches of literature, to consult and to critically use scientific databases and other appropriate sources of information, to carry out simulation and analysis in order to pursue detailed investigations and research of technical issues in their field of study;
- ability to consult and apply codes of practice and safety regulations in their field of study;
- laboratory/workshop skills and ability to design and conduct experimental investigations, interpret data and draw conclusions in their field of study.

Learning area 5: Engineering Practice
The learning process should enable **Bachelor Degree graduates to demonstrate:**

- understanding of applicable techniques and methods of analysis, design and investigation and of their limitations in their field of study;
- practical skills for solving complex problems, realising complex engineering designs and conducting investigations in their field of study;
- understanding of applicable materials, equipment and tools, engineering technologies and processes, and of their limitations in their field of study;
- ability to apply norms of engineering practice in their field of study;
- awareness of non-technical -societal, health and safety, environmental, economic and industrial – implications of engineering practice;
- awareness of economic, organisational and managerial issues (such as project management, risk and change management) in the industrial and business context.

Learning area 6: Making Judgements Communication and Team-working
The learning process should enable **Bachelor Degree graduates to demonstrate:**

- ability to gather and interpret relevant data and handle complexity within their field of study, to inform judgements that include reflection on relevant social and ethical issues;
- ability to manage complex technical or professional activities or projects in their field of study, taking responsibility for decision making.

Learning area 7: Lifelong Learning
The learning process should enable **Bachelor Degree graduates to demonstrate:**

- ability to recognise the need for and to engage in independent life-long learning; ability to follow developments in science and technology.

Box 2
Programme outcomes for master's degrees in EUR-ACE (extracted from ENAEE) organized by learning areas.

Learning area 1: Knowledge and Understanding
The learning process should enable **Master Degree graduates to demonstrate:**

- in-depth knowledge and understanding of mathematics, computing and sciences underlying their engineering specialisation, at a level necessary to achieve the other programme outcomes;
- in-depth knowledge and understanding of engineering disciplines underlying their specialisation, at a level necessary to achieve the other programme outcomes;
- critical awareness of the forefront of their specialisation;
- critical awareness of the wider multidisciplinary context of engineering and of knowledge issues at the interface between different fields.

(*continued on next page*)

Box 2 (*continued*)

Learning area 2: Engineering Analysis

The learning process should enable **Master Degree graduates to demonstrate:**

- ability to analyse new and complex engineering products, processes and systems within broader or multidisciplinary contexts; to select and apply the most appropriate and relevant methods from established analytical, computational and experimental methods or new and innovative methods; to critically interpret the outcomes of such analyses;
- ability to conceptualise engineering products, processes and systems;
- ability to identify, formulate and solve unfamiliar complex engineering problems that are incompletely defined, have competing specifications, may involve considerations from outside their field of study and non-technical – societal, health and safety, environmental, economic and industrial – constraints; to select and apply the most appropriate and relevant methods from established analytical, computational and experimental methods or new and innovative methods in problem solving;
- ability to identify, formulate and solve complex problems in new and emerging areas of their specialisation.

Learning area 3: Engineering Design

The learning process should enable **Master Degree graduates to demonstrate:**

- ability to develop, to design new and complex products (devices, artefacts, etc.), processes and systems, with specifications incompletely defined and/or competing, that require integration of knowledge from different fields and non-technical – societal, health and safety, environmental, economic and industrial commercial – constraints; to select and apply the most appropriate and relevant design methodologies or to use creativity to develop new and original design methodologies.
- ability to design using knowledge and understanding at the forefront of their engineering specialisation.

Learning area 4: Investigations

The learning process should enable **Master Degree graduates to demonstrate:**

- ability to identify, locate and obtain required data;
- ability to conduct searches of literature, to consult and critically use databases and other sources of information, to carry out simulation in order to pursue detailed investigations and research of complex technical issues;
- ability to consult and apply codes of practice and safety regulations;
- advanced laboratory/workshop skills and ability to design and conduct experimental investigations, critically evaluate data and draw conclusions;
- ability to investigate in a creative way the application of new and emerging technologies at the forefront of their engineering specialisation.

Learning area 5: Engineering Practice

The learning process should enable **Master Degree graduates to demonstrate:**

- comprehensive understanding of applicable techniques and methods of analysis, design and investigation and of their limitations;
- practical skills, including the use of computer tools, for solving complex problems, realising complex engineering design, designing and conducting complex investigations;
- comprehensive understanding of applicable materials, equipment and tools, engineering technologies and processes, and of their limitations;
- ability to apply norms of engineering practice;
- knowledge and understanding of the non-technical – societal, health and safety, environmental, economic and industrial – implications of engineering practice;
- critical awareness of economic, organisational and managerial issues (such as project management, risk and change management)

Learning area 6: Making Judgement Skills Communication and Team-working Skills

The learning process should enable **Master Degree graduates to demonstrate:**

- ability to integrate knowledge and handle complexity, to formulate judgements with incomplete or limited information, that include reflecting on social and ethical responsibilities linked to the application of their knowledge and judgement to deliver sustainable solutions for society, the economy and environment;
- ability to manage complex technical or professional activities or projects that can require new strategic approaches, taking responsibility for decision making.

Learning area 7: Lifelong Learning Skills

The learning process should enable **Master Degree graduates to demonstrate:**

- ability to engage in independent life-long learning; ability to undertake further study autonomously.

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