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Overview of the current situation relating to chemical engineering degree courses

María-Fernanda López-Pérez [a,*], Ma Ángeles Larrubia [b], Alejandro Fernández [c], Julià Sempere [d]

[a] Department of Chemical Engineering and Nuclear, Universitat Poltècnica de València, Plaza Ferràndiz-Carbonell s/n, Alcoy, Spain
[b] Department of Chemical Engineering. Universidad de Málaga, Campus de Teatino s/n, Málaga, Spain
[c] Department of Chemical Engineering, Universidad de Granada, Avda. del Hospicio, s/n, Granada, Spain
[d] IQS School of Engineering, Vía Augusta, 390, Barcelona, Spain

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ABSTRACT

In 2020, the Conference of Chemical Engineering Directors and Deans (CODDIQ) proposed the creation of an observatory to monitor chemical engineering degrees in Spain. This representative radiography of Chemical Engineering studies offers an initial point to observe the future changes when Royal Decree 822/2021 and proposed challenges in the last Ministerial Conference on the European Higher Education Area (EHEA) will be implanted. The survey data from CODDIQ partners allow us to know important data such as (i) the 24 international quality accreditations at Spanish universities, (ii) the high demand and the required marks, an average of 7.25, for the Chemical Engineering Bachelor's degree, (iii) 9560 undergraduate students in this degree in Spain and their gender profile which is around 43% of women, similar than women lectures, (iv) the difficulty of this Bachelor's degree through some indicators like duration of studies (5.25 years), graduation rate (41%) and drop-out rate (26%), (v) the employability after obtaining the Bachelor's degree is very high (>70%). In addition, Chemical engineering undergraduate and graduate students indicate their expectations are covered. In this paper, some consequences of the pandemic on students' performance (lower than before COVID-19) are analyzed, despite lectures tried to innovate in their classes and the university provided adequate tools for online teaching.

1. Framework of chemical engineering studies in Spain

The European Higher Education Area (EHEA), established by 48 countries, has evolved over 23 years and has contributed to important progress made over two decades when it comes to mobility, quality assurance and recognition. European higher education systems advanced with concerted national reforms and its evolution in Spain depends on the work that is undertaken now. A summary of the actual regulatory framework in Spain is shown to understand towards university education goes.

The last Ministerial Conference on the European Higher Education Area (EHEA) took place in Rome on 19 November 2020. This event, which was held virtually for the first time due to the pandemic, brought together the ministries responsible for higher education along with other representatives from the sector.

The conference highlighted the unique opportunities offered by the EHEA by virtue of its diversity of cultures, languages and environments and the common commitment to quality, transparency and mobility, whilst also paying tribute to the efforts made by the university community during the COVID-19 pandemic. In addition, the communiqué assessed the progress made in implementing the EHEA since the Bologna Declaration 23 years ago and the progress made on the objectives set at the previous Ministerial Conference held in Paris in 2018, while then setting out the general lines of work and objectives for the coming years and for the future of higher education in Europe until 2030 (Rome Ministerial Communiqué).

Universities are key actors in this process and they recognise the importance of a commitment to achieving Sustainable Development Goals (SDGs) in a wide-ranging manner. In order to achieve these overall goals, universities have implemented training initiatives that include introducing more innovative and participatory teaching methods, the incorporation of new competences and skills into study plans to promote the analysis of holistic sustainability in the curricula, support for designing criteria and indicators aligned with the SDGs in university

* Corresponding author.
E-mail address: malope1@iqn.upv.es (M.-F. López-Pérez).

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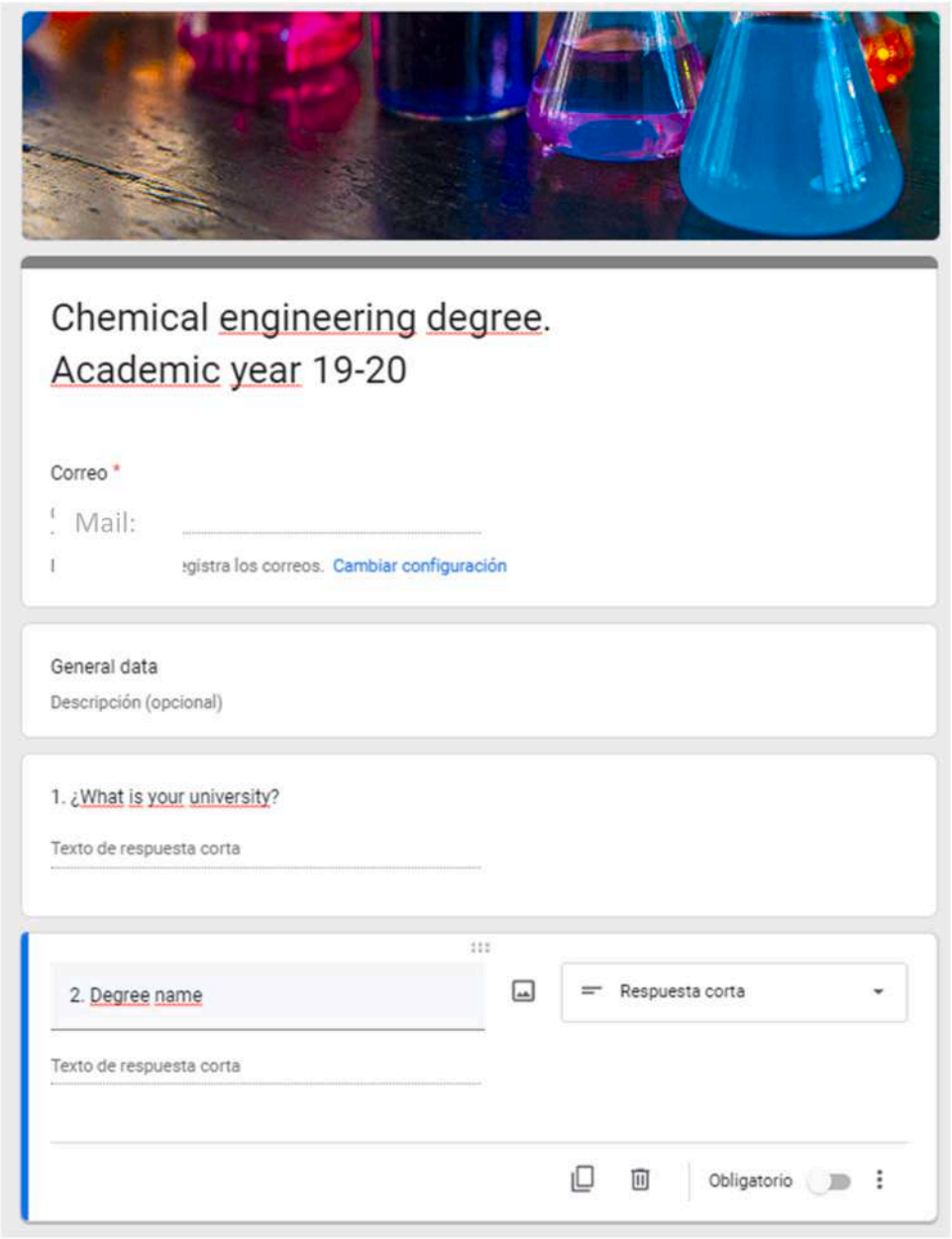

Fig. 1. Survey carried out on CODDIQ member centres where a degree in chemical engineering is taught in Spain.

quality assessment systems and favouring inclusive education and multidisciplinary competences for global citizenship, among others (Amanda Doyle, 2021).

Bachelor's and master's degree courses in chemical engineering in Spain fit within this framework (Miranda et al., 2022), and they have been adapted to the recommendations of the EHEA Project. All these adaptations, along with societal changes and the new generations of students, mean that universities, and therefore their degrees, are evolving over time.

Hence, Royal Decree 822/2021, of 28 september (BOE, 2021) has been presented, which organization of university education and the procedure for ensuring its quality is established. The Royal Decree 822/2021 maintains the basic structure of the academic offer: Bachelor's, Master's and Doctorate, although it introduces significant modifications. One of the innovations of Royal Decree 822/2021 is the change in the assignment of the degree programs to a field of knowledge. Although up to now all degree programs had to be linked to one of the five branches of knowledge, from the entry into force of the Royal Decree each degree becomes assigned to one of the 32 areas of knowledge. Chemical engineering, engineering of materials and engineering of the natural environment is one of these areas of knowledge. Another important modification is official university Bachelor's and Master's degrees may include the Dual Mention, which involves a common training project that is developed complementarily in the university center and in a collaborating entity, which may be a company, a social or trade union organization, an institution or an administration, under the supervision and training leaders of the university center, and whose objective is the appropriate training of students to improve their comprehensive training and improve their employability.

In 2018, Feijoo et al. (2018) published a snapshot of the state of chemical engineering education in Spain. However, these indicators have continued evolving with the arrival of subsequent generations and it is essential we continue analysing them in order to determine whether changes need to be made to our teaching-learning methodologies. As a result of these changes, the Conference of Chemical Engineering Directors and Deans (CODDIQ, www.coddiq.es) proposed the creation of

an observatory to monitor chemical engineering degrees in Spain. This observatory would be responsible for studying the current situation regarding bachelor's, master's and doctoral degrees in chemical engineering.

This paper presents the results obtained from these studies and, therefore, represents an up-to-date overview of chemical engineering bachelor's degrees. This instant photo offers an initial point to observe the future changes when Royal Decree 822/2021 will be implanted.

2. Surveys and databases

Numerous databases and information sources were used to obtain the data presented in this paper, in addition to using surveys as a data collection tool. The surveys were conducted among CODDIQ members following a planned investigation based on the Design and Analysis of Surveys technique, DYANE (Casas Anguita et al., 2003). The survey process consists of four main stages: (1) Planning; (2) Collecting; (3) Analysing; and (4) Presenting. The surveys are conducted in a wide variety of techniques including Google forms surveys, which were used.

The first step applied in this methodology is the planning process, which is divided into different actions such as:

1. Identification of the problem: the main objective of the surveys carried out was to obtain information on indicators related to the Quality Assessment Programmes by the National Agency for Quality Assessment and Accreditation (ANECA, http://www.aneca.es/) and indicators related to the employability of graduates with chemical engineering degrees in Spain. These are the study variables that help to develop the questionary and its format, and they are available data for all survey respondents. Once the variables are determined, a closed response format was chosen.
2. Sample selection: as mentioned above, the 31 schools and faculties of the universities associated with CODDIQ were chosen as the units that made up the population. Of these, the final sample consisted of 24 responses. The sample size was considered acceptable, given that bachelor's degrees in chemical engineering of CODDIQ are taught in 36 universities in Spain. With a population of 31 schools and faculties, 24 surveys are needed to have a confidence level of 95% that the real value is within ± 10% of the surveyed value. The Google Forms link was sent by mail to CODDIQ members in order to an academic manager or administrative people of the chemical engineering degree could be answered the surveys.
3. Questionnaire design: The questions were organised in such a way as to obtain information related to both students and teachers.
4. Type of questions: most of the questions were open-ended, as they were based on numerical data, although there were also closed questions (Yes/No, True/False) and multiple-choice questions. The questions were grouped by topic for ease of answering. They are familiar to most respondents and for this reason easy and fast to answer.

The second step is survey collection. The surveys were conducted using the Google Forms tool (Fig. 1), they were sent by email and analysed one month later. A Survey is available in this link: https://forms.gle/TptK7KRRH2Gi2JXq9.

The next steps are survey analysis and presentation which involve a descriptive study of different variables and which are presented in this work.

For the analysis of data, some questions were proposed:

- What are the most common responses to questions X?
- Which responses are affecting/impacting us the most?
- What's different about this month/this year?
- What did respondents in group Y say?
- Which group of respondents are most affected by issue Z?
- Have customers noticed our efforts in solving issue Z?
- What do people say about Z?

To always make sure you have a sufficient sample size, how many people are needed to survey in order to get an accurate result was considered, although in this case the people were limited by universities associated with CODDIQ, and for this reason, the answers are confidence for the decision making.

Table 1
Evolution of marks obtained in the university entrance exams in Spain during 2015–2021 period.

Year	Minimum	Maximum
2015	6.9	7.3
2016	7.0	7.4
2017	7.1	7.6
2018	7.1	7.7
2019	7.2	7.8
2020	7.3	7.9
2022	7.4	8.1

3. International accreditations

The objective of the ACREDITA programme, which is administered by ANECA, is to evaluate official university bachelor's degrees with a view to renewing their accreditation. This evaluation is carried out on a cyclical basis and a final report is issued either recommending accreditation or withholding approval for accreditation. This compulsory process must be passed in Spain in order to continue teaching the degree. However, there are other types of international quality accreditations such as the European EUR-ACE label awarded to accredited engineering degree programmes, the IChemE accreditation of degree programmes or ABET's Engineering Technology Accreditation Commission which all certify that degree programmes surpass the requirements demanded in professional engineering.

Spanish centres have improved significantly in this regard, since, in 2018 (Feijoo et al., 2018), only 5 out of the 44 chemical engineering degrees taught in Spain had the EUR-ACE label, 2 degrees had the IChemE international quality seal and 1 degree had the ABET accreditation. While, currently, 21 chemical engineering degrees have obtained the EUR-ACE label. The chemical engineering degrees taught at the Universities of Oviedo and Santiago de Compostela maintain their IChemE accreditation and the Instituto Químico de Sarrià (IQS) maintains its ABET accreditation.

This progression indicates the engagement of the university community with this degree, coinciding with the increase in demand, both from companies and from the students themselves. While chemical engineering is one of the most challenging university degrees, the multiple career opportunities it offers means that mastering the subject and its equations increases our motivation to make the world a better place.

4. Students studying chemical engineering degrees in Spain

An important indicator that allows the university system to understand how its bachelor's degrees in chemical engineering are doing is to count the number of new students. These students access their studies by means of a mark obtained in the university entrance exams, which remains around 7.5 on average across Spain, with no major differences between autonomous communities, as the minimum mark is 7.4 and the maximum is 8.1 in high school studies (Score between 0 and 10). These marks have increased every year because from 2015 to 2021 the maximum score augmented from 7.3 to 7.9 (Table 1). This data can be consulted on the webside: https://public.tableau.com/views/EBAU_21/Dashboard1?%3AshowVizHome=no&%3Aembed=true#1 Sistema Integrado de Información Universitaria (SIIU).

The entrance marks for a degree course in chemical engineering are noticeably uneven due to the fact that there are universities with high

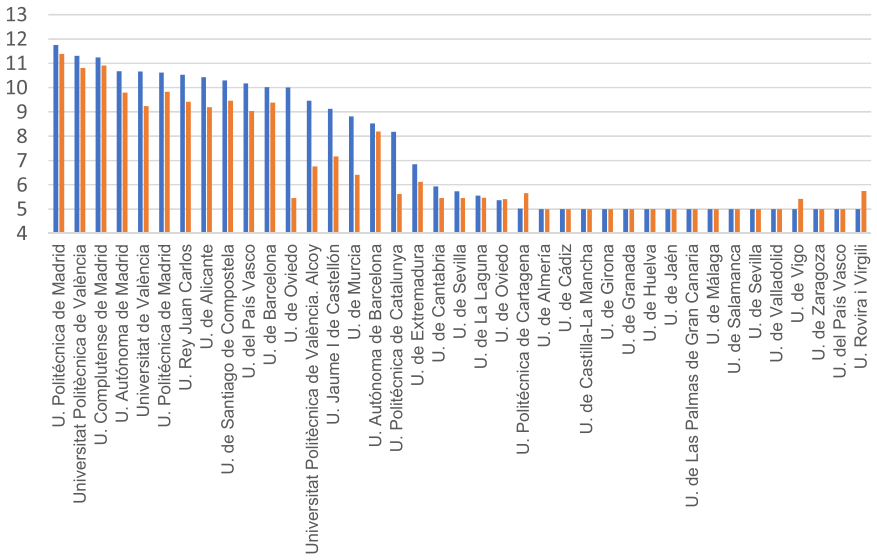

Fig. 2. Access marks for degrees in chemical engineering in Spain (out of 14) ■ Marks in year 20–21 ■ Marks in year 21–22.

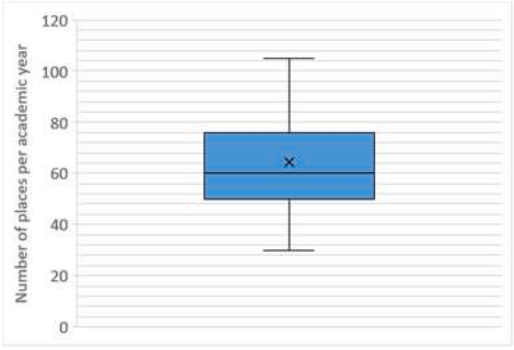

Fig. 3. Number of places offered per academic year in Spanish universities to study degrees in chemical engineering (academic year 22–23).

demand, such as the Polytechnic University of Madrid or the Polytechnic University of Valencia, whose marks are above 10.00, and other universities where demand is lower, which require marks of 5.00. The university access mark must be higher than 5 points. However, students can reach since 14 points in their score because not only the mark obtained in the university entrance exams is borne in mind. They can achieve additional four points when they do an optional exam on related subjects with the chosen degree. On average, the cut-off mark has increased in the 22–23 academic year, with an average mark of 7.25, compared to the previous year's mark of 6.72, suggesting that the demand for the degree has increased this year. For example, the score in Universitat Politècnica de València has increase from 10.379 in year 16–17–11.387 in year 20–21. Nevertheless, Feijoo (Feijoo G., 2016) showed a minimum access score of over 6.8 and an average grade of 8.8 between 2014 and 2017, indicating that there is high variability in the entrance of students in each university and that the increase in marks in university entrance exams can be another factor to consider. Fig. 2 shows the differences between the cut-off marks for degrees in chemical engineering at Spanish universities (survey data and https://www.educacion.gob.es/notasdecorte).

In terms of places offered in Spain, engineering and architecture, as area of knowledge, represents 22% of the total number of places offered, surpassed by health and social services and business, administration and law. A total of 53,331 places are offered per year in engineering and architecture area, of which 4.7%, i.e. 2507 places are offered for degrees in chemical engineering. The average number of places in the first year offered in Spanish universities for this degree is 64 places, although there are universities that offer more than 100 places and others that do not exceed 30 places per year (Fig. 3). This number of offered places is

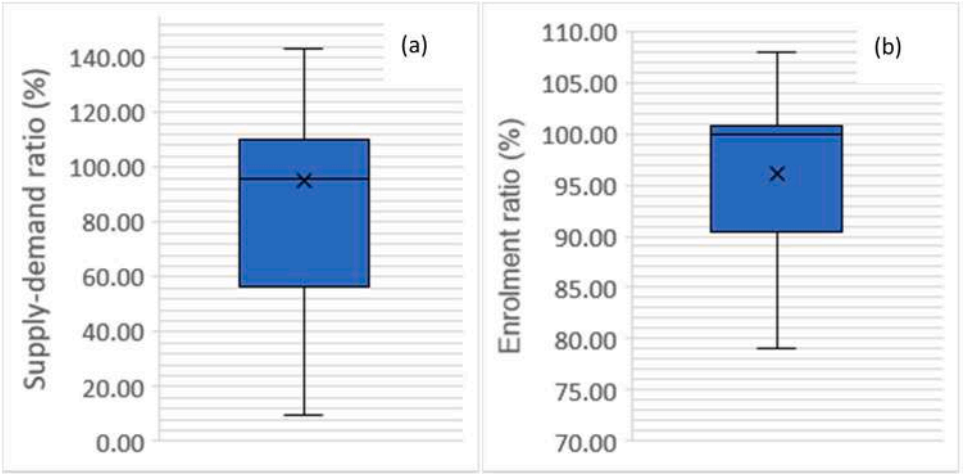

Fig. 4. (a) Supply-demand ratio (%), (b) Enrolment ratio for degrees in chemical engineering (%).

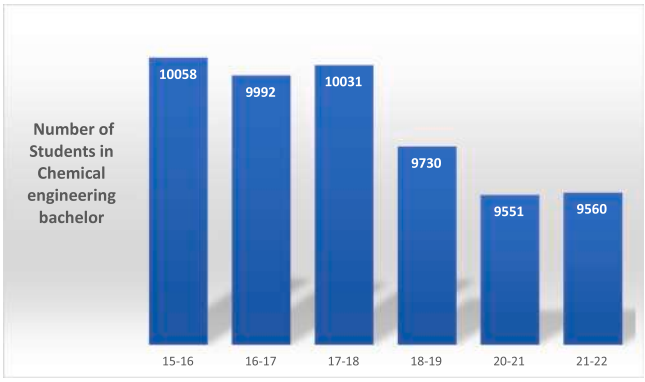

Fig. 5. Number of students enrolled to study chemical engineering degrees in Spain.

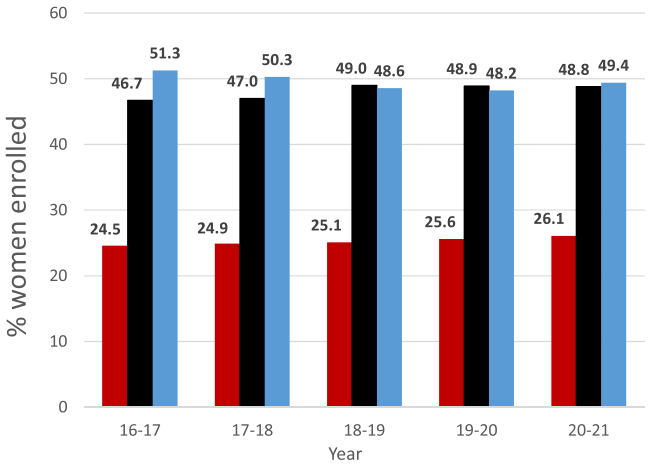

Fig. 6. Percentage of women enrolled in any year. ● Chemical engineering degree, ● Chemical engineering degree graduate ● Total engenieering degrees.

constant because is reflected in Agencia Nacional de Evaluación de la Calidad y Acreditación (ANECA) verification report (ANECA - Aneca Web). A change in the number of offered places is considered a substantial modification and it has to be processed under the provisions for the verification process of the study plans by Quality Agency (BOE, 2021) Real Decreto 822/2021 and it has to indicate by every Autonomous Regions in Spain.

There are two parameters that indicate the demand for chemical engineering as an option to study after the entrance exams. One of these is the percentage ratio between the number of students who apply to study chemical engineering as a first or second choice compared to other degrees and the places offered, which for a degree in chemical engineering is 88% on average (supply-demand ratio). The other is the enrolment ratio, with the percentage ratio between the number of new students enrolling in the degree compared to the places offered being 82.8%. As can be seen, these figures are high, although the variation between universities is large, as there are degrees with supply and demand or enrolment rates that exceed 100, and some others that are much lower (Fig. 4).

However, annual enrolment is progressively decreasing, with 62 new students in the 19–20 academic year and 55 in the 20–21 academic year. Since the 15–16 academic year, the number of students enrolled for degrees in chemical engineering has decreased despite the high demand from students who want to study engineering (indicated by the supply-demand ratio). This can be interpreted in different ways, as this decrease may be indicative of the drop in the birth rate in Spain (7.12 per thousand inhabitants in 2021 vs 9.02 per thousand inhabitants in 2015), of the increase in the number of students who do not pursue university studies and who opt instead for other options such as vocational training (from 16 to 17 year enrolled students in this type of education have increased almost two hundred thousand students) or the increase in the number of bachelors related to the area of engineering and architecture (in the15–16 academic year there were 743 degrees relate with engineering and architecture area and in the 21–22 academic year this number increased until 838 degree in the same area).

Looking at the variations in the total student population within the EHEA over time, a similar tendency was observed, although the pattern in some countries differs. Between 2010 and 2015, Turkey recorded an increase in student numbers of 71.8%. This was far beyond the next highest countries – Albania and Denmark – which were close to 30%. In contrast, decreases in student numbers were apparent in about half of the EHEA countries, including four of the larger countries (France, Italy, Ukraine and Poland). Decreases were most pronounced in Romania and North Macedonia (both above 45%). These changes over time should be viewed in combination with other factors, such as demographic changes (increases or decreases in the size of young population cohorts) and Changes in economic conditions (European Commission)). Compared to the 15–16 academic year, there are 5% fewer students in chemical engineering degrees (Fig. 5). In the coming years, this trend should be observed in order to take appropriate measures.

In terms of the percentage of women and men enrolled in the chemical engineering degrees offered in Spain, it is much more balanced than in other engineering degrees, as there are some universities where half of their first-year students are women. In the 16–17 academic year (Feijoo et al., 2018) the average percentage of female enrolment in the first year was around 46.5%, At the first year of the degree, the women enrolment has decreased, with the percentage in the 19–20 academic year being 45.1% and 43% in 20–21 (data from surveys). Even with this decrease in the number of women in the first year of chemical engineering degrees, the percentage of women studying the degree is maintained and even increases slightly with respect to previous years (Fig. 6), which may indicate that the drop-out rate during studies is higher for men than for women (Ministerio de Universidades, 2021). This data is in line with the situation in all degrees in all academic disciplines, as it has been shown that the drop-out and change of studies rates in the first year of the degree is higher in all cases for men than for women. In engineering and architecture 19% of women drop out compared to 26.9% of men and 9.5% of women change degree compared to 11.5% of men. Even with a slight decrease, the percentage of women studying chemical engineering is much higher than the percentage of women enrolled in engineering degrees in general, which is 24% (https://www.universidades.gob.es/portal/site/universidades/). However, in recent years, the number of women enrolled in engineering and architecture has increased slightly to an average percentage of 26% in the 21–22 academic year, although this is below the European average for engineering manufacturing and construction, which is 28.6% (https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Main_Page).

When the percentage of women entering tertiary education in Europe is observed, in many countries, this percentage exceeded 50% in 2017, being over 60% in Albania and Iceland. Luxemburg, Ukraine, Germany, Cyprus and Switzerland almost reached gender parity. Male entrants are the majority in Turkey and Andorra, but gender imbalance was stronger in Liechtenstein and Russia where female participation was below 36%. the change since 2005, the EHEA median stayed relatively stable (around 54%), but it had a slight decrease over the twelve years. Albania and Turkey however managed to triple the number of female entrants since 2005, achieving also the highest increase in the share of women (8.3% and 14.1% respectively), along with Poland (8.9%). A few other countries saw a further increase in the share of women, but to a much lesser degree: Greece (5.6%), Switzerland (5.7%), Czechia (7.0%) and Slovakia (7.2%). In the same way as in Spain, when these numbers are considered about the gender split in different fields, the largest

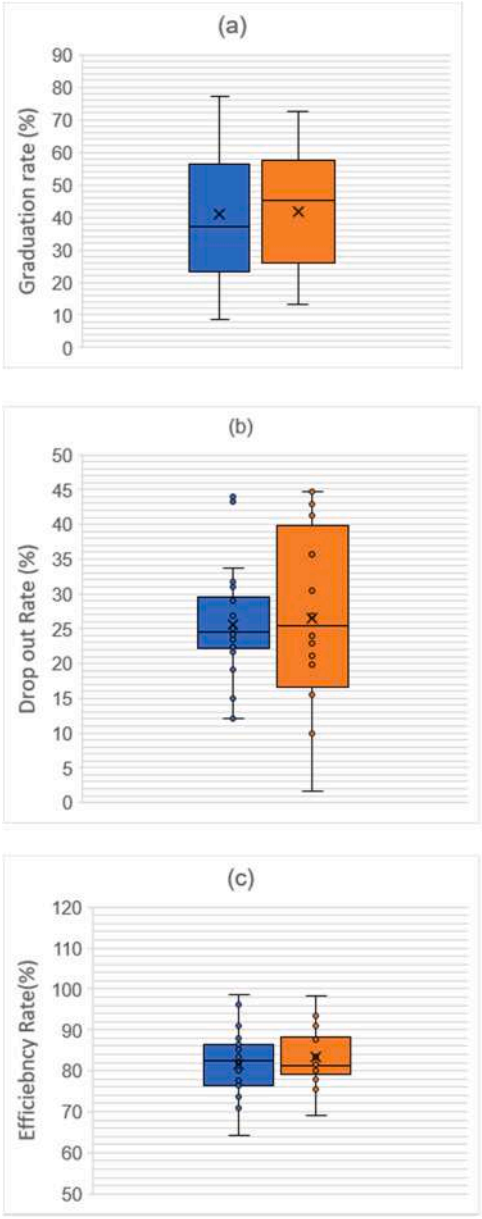

Fig. 7. Indicators for Chemical Engineering Degrees in academic year 20–21. (a) Graduation rate, (b) Drop-out rate, (c) Efficiency rate. ● Academic year 19–20, ● Academic year 20–21.

number of female students are found in business-related programs (56.4%), health studies (76%), education field (78.6%), followed by arts (65.2%) and social sciences (64.4%). The opposite trend can be seen regarding female participation in information and communication technologies (17.8%), as well as in engineering, manufacturing and construction (25.5%), both fields of study where women are strongly under-represented. (European Commission)

5. Degree Indicators to monitor the learning outcome

These very positive figures for student enrolment are not reflected in the indicators related to the average duration of studies, the graduation rate or the drop-out rate. During the 19–20 academic year, we exceeded an average of 4 years duration for studies to obtain a degree, which would be the optimal value, and we currently have a value of 5.25 (academic year 20–21). In all these data, there is great disparity between universities, with some universities having an average duration of 6.5 years, while others have an average duration of 4.5 years. The rest of the universities are in a range of 5–5.5 years for the average duration of studies.

Table 2
Comparison of indicative quality parameters in different academic disciplines (Ministerio de Universidades, 2021).

	Graduation rate (%)	Drop-out rate (%)	Efficiency rate (%)
Social and Legal Sciences	20.4	52.4	90.5
Engineering and Architecture	25.2	30.8	82.5
Arts and Humanities	28.6	44.4	91.1
Health Sciences	17.7	69.9	93.2
Science	23.3	47.0	87.1

The duration parameter is related to the graduation rate data, which in Spain has been defined as the annual proportion of students who manage to finish their degree in the expected time plus one year, with respect to the initially enrolled students, this figure is low, since the average is 41.1%, with values of 21% in some universities in academic year 19–20 (Fig. 7a). A departure from the 100% rate indicates the difficulty of the curriculum and coincides with a longer average duration. Degrees with high graduation rates, above 70%, have an average study duration of 4 years. For this parameter, there is also great variability in the data between Spanish universities, although almost all of them have a higher rate than the average found in engineering and architecture area, which has very low values (25.2%). The performance rate of the degree (the relationship between the number of credits passed in year X and the total number of ordinary credits enrolled on for this degree) is a parameter also related to the difficulty of the degree. It shows the difficulty or ease with which students pass the subjects in which they enrol and is above 73%, higher than the average for engineering, which is 68%. In this study, a direct relationship between the performance rate of the degree and the entrance score is not observed, because there are universities with lower scores and they have higher performance rates. The difficulty of chemical engineering degrees, like that of other engineering degrees, is indisputable since, when we look at the marks in the academic record (graduate students) for engineering degrees and compare them with the marks in other academic disciplines, the level drops from marks that exceed 7.14 in all cases to 6.86 (Ministerio de universidades, 2021). Other parameters that help us to understand how chemical engineering degrees are doing are the drop-out rate of students in the first and second year and the efficiency rate for the graduates that started the degree in the same year (percentage ratio between credits passed and credits enrolled on). The drop-out rate is around 26%, although this data changed in 20–21 academic year in a lot of universities possibly due to the pandemic (Fig. 7b), and an average efficiency rate of 82.5% (Fig. 7c). Both have similar values to the averages for engineering and architecture (Table 2). It is a problem that needs to be addressed as there are multiple reasons why these may be high. It may be due to various causes such as a lack of guidance and prior training of students, the expectations generated and not fulfilled in the first years, inadequate design of curricula, poor monitoring of students or low quality of teaching, poor academic performance of students due to lack of ability, effort or motivation or inadequate requirement level (Fundación 2022; López-Cózar-Navarro et al., 2020). The pandemic is going to have an enormous influence on all the above indicators, although these changes will be observed in the next years (Vargas-Ramos et al., 2022).

These problems are even more significant in other academic disciplines, such as health sciences, where drop-out rates are much higher than for engineering and architecture, which may indicate that students who enroll on chemical engineering degrees have a vocation or see a way through their degree so as not to abandon it once they have started it, even though they fail more than in the other academic disciplines.

Table 3
Average assessment of the degree of satisfaction of students on chemical engineering degrees.

	Rating (scale 1–10)
Degree of satisfaction with lecturers	7.29
Degree of satisfaction with resources	7.65
Degree of satisfaction with the bachelor's degree	7.56

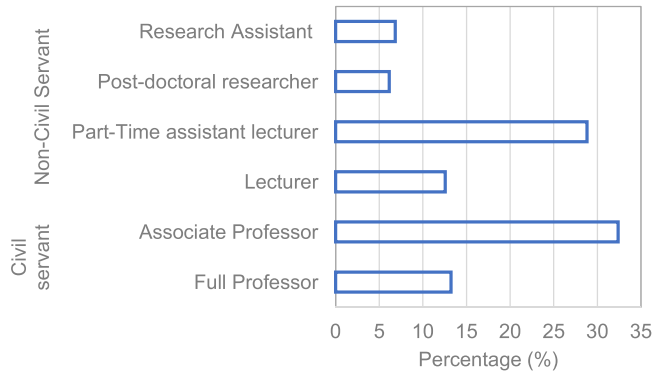

Fig. 8. Teaching and research staff at Spanish universities Sistema Integrado de Información Universitaria (SIIU).

6. Satisfaction indicators

Despite the above data indicating the difficulty of chemical engineering degrees, the satisfaction indicators from the students studying this degree are surprisingly high, indicating that the quality of the teaching they are receiving is in line with their expectations. On a scale of 1–10, undergraduate students give values higher than 7.0 on average, both for the degree in general, and for their teachers and the resources (Table 3).

Even the graduates rate the degrees very positively, their level of satisfaction with the university is higher when they have finished their studies, their expectations were lower compared to what, at the end, they perceive they have received from the institution. The average rating is 7.6.

The lecturers who teach chemical engineering degrees are also satisfied with the degree, awarding a rating of 8.1.

The data of these satisfaction indicators are often collected by universities using phone interviews, self-report paper questionnaires and email questionnaires.

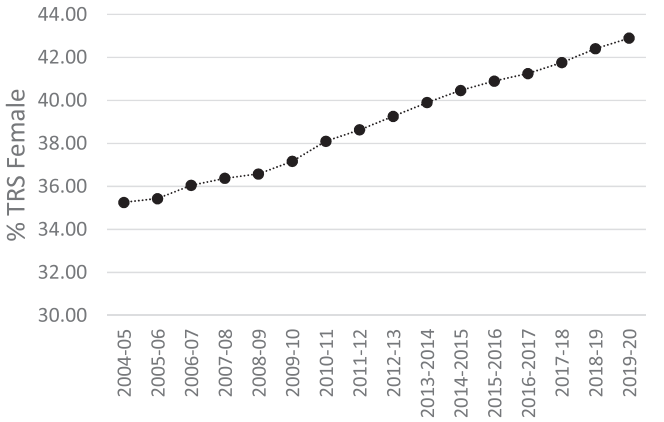

Fig. 10. Evolution of female percentage teaching and research staff (TRS) (%).

7. Lecturers. Teaching and research staff

There are several categories of lecturers in Spanish universities, of which the most common category is that of Tenured University Lecturer (Full and Associate Professor, civil servants) with 45.62% of the total during the 21–22 academic year. However, the percentage of Part-Time assistant lecturers is 23.86% of the total number of university lecturers; these are specialists with recognised competence who are hired to offer knowledge related to their professional activity, although most of the time they teach subjects that are not related to their profession. It is a figure that the public universities rely on as there are not enough tenured lecturers to cover all the teaching and research needs (Fig. 8). For chemical engineering degrees, there is great variability in the data, as there are between 5% and 20% associate lecturers, depending on the policy of each university.

Another striking fact is the age of the teaching staff in Spanish universities: the percentage of lecturers in the 50–60 age bracket is 35.68%, followed by the 40–50 age bracket with 29.52%. As can be seen, university staff are ageing, as only 8.99% of the total are between 35 and 40 years old and 6.88% are under 35 years old. The average age of chemical engineering degree lecturers coincides with the average age of Spanish university lecturers. The analysis of the average age of chemical engineering academic staff in Europe shows a similar tendency (Bogle, 2021). Denmark, Slovenia, Sweden, and Lithuania are at the lower end. In Spain and Italy, national competitions are organised and this can control the number of posts that are opened. Ukraine confirmed that there has been low recruitment in recent years. Italy has had recruitment freezes in the last decade. The financial situation in Greece has affected recruitment in universities (Fig. 9).

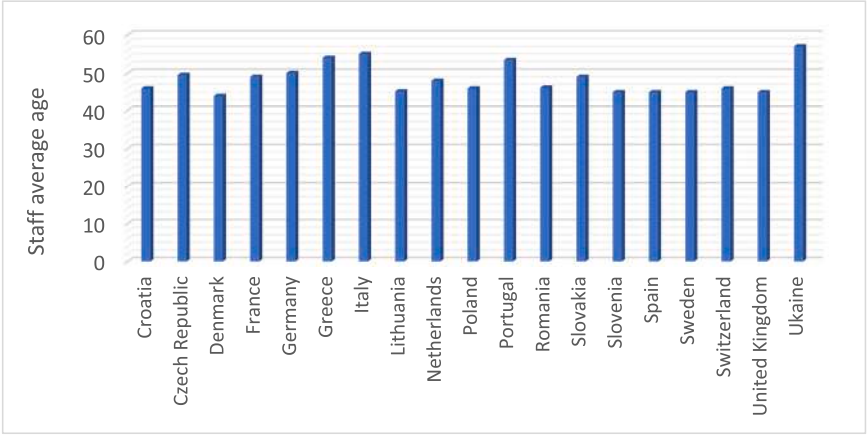

Fig. 9. Chemical engineering staff average age in Europe.

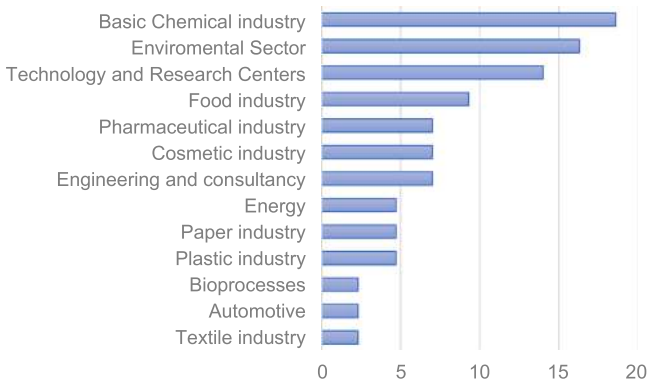

Fig. 11. Industrial sectors where students carry out their work placements.

In terms of the number of women on universities' teaching and research staff, this has increased slightly since the 15–16 academic year, reaching 42.7% in the 20–21 academic year. However, the number of women has grown considerably since the 2004–05 academic year (Fig. 10). In the case of the lecturers teaching subjects on chemical engineering degrees, women account for 40.6% of the total, which is within the university average, although well above the percentage that can be observed for engineering and architecture area, which is only 23.4%. The percentage of female teachers both in chemical engineering and in the average percentage for engineering and architecture area is lower than the percentage of female students, especially if phD female students are analyzed, because the number increase to 30% in 20–21 academic year. This indicates that there is more parity in the younger generations. In fact, when looking at the ratio of university lecturers under 40 years of age, the percentage for women is 17.09%, while this value for men is 11.4% of the total teachers Sistema Integrado de Información Universitaria (SIIU).

In 2017, in half of the countries of EHEA more than 45% of the staff was female (European Commission). Across countries, there were wide variations. 12 countries had an academic staff population where women were the majority sex. Greece (34.3%), Switzerland (35.5%) and Malta (35.8%) were the systems with the lowest proportion of women among the academic staff population. Compared to 2000, the share of female staff had increased in all countries except Albania, Greece, Luxembourg and Latvia. Slovenia had the most significant increase (84.4%) between 2000 and 2017, followed by Malta (59.1%) and Montenegro (42.9%).

8. Chemical engineering in society

Degrees in chemical engineering include a number of hours dedicated to work placements during the period of their studies, which help students to become effective professionals who are confident of their potential. These placements provide valid experience for the student's CV, contacts related to the professional field in order to be able to access job offers, and perhaps even an opportunity for the company to hire the student in the future. It is worth noting that, for example, at the University of Barcelona, 38.5% of students who do a work placement obtain an employment contract.

The industrial sectors to which our students gain access are those related to chemical engineering, ranging from the basic chemical, petrochemical and pharmaceutical industry to all the sectors derived from it (paper industry, bioprocesses, food, automotive, plastics, cosmetics, textiles), without forgetting such important sectors as the energy and environmental sectors. Some of our students also do work placements in other sectors such as engineering and consultancy, as well as at Technology and Research Centres. The distribution of sectors where students carry out their work placements remains very similar to that in previous years (Feijoo et al., 2018), with the most important being the basic chemical industry and the environmental sector (Fig. 11).

The companies where the students do their work placements are mostly companies with more than 50 employees where they perform a wide range of functions, including undertaking projects, plant work, control, safety or environmental applications. These tasks are complemented by the preparation of technical documentation, analysis and quality control, although these tasks are mainly carried out in SMEs, where the range of jobs that students can perform within the company is more limited. With regard to the degree of satisfaction indicated by the students with the work placement, the score is 8.44 out of 10.00.

In addition to offering students the opportunity to come into contact with real jobs and put their knowledge into practice, the main objective of a chemical engineering degree is to train professionals who can find and apply in a job everything they have learnt during their studies. In this aspect, the recruitment of students who have studied chemical engineering is uneven: those students who work in areas where the receiving companies are SMEs, the employment rates are higher than 70%, but this rate drops when the company has more than 50 workers, where they are lower, 30–50%, possibly due to the need by these companies for greater specialisation. However, the score for the extent to which students feel the job is related to their degree shows opposite values: those students who work in SMEs give an average score of 6.5, while those who work in larger companies, the degree of satisfaction is

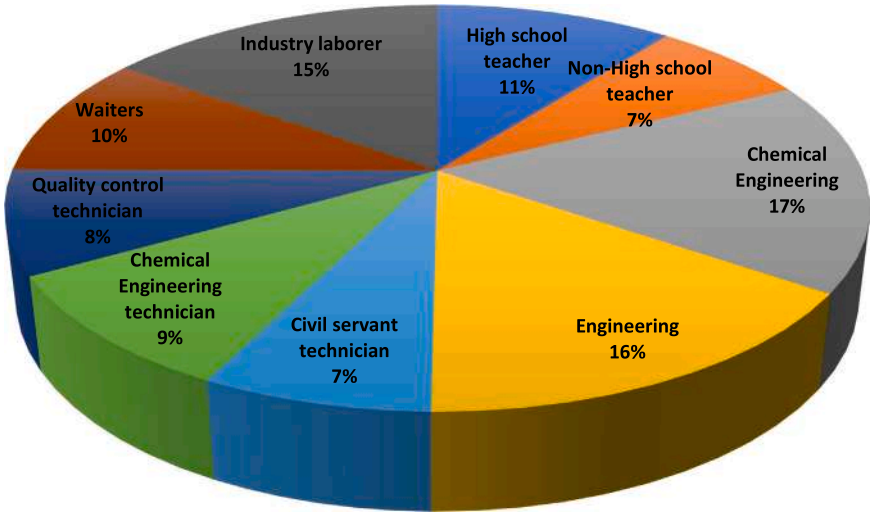

Fig. 12. Jobs employing chemical engineering graduates most frequently.

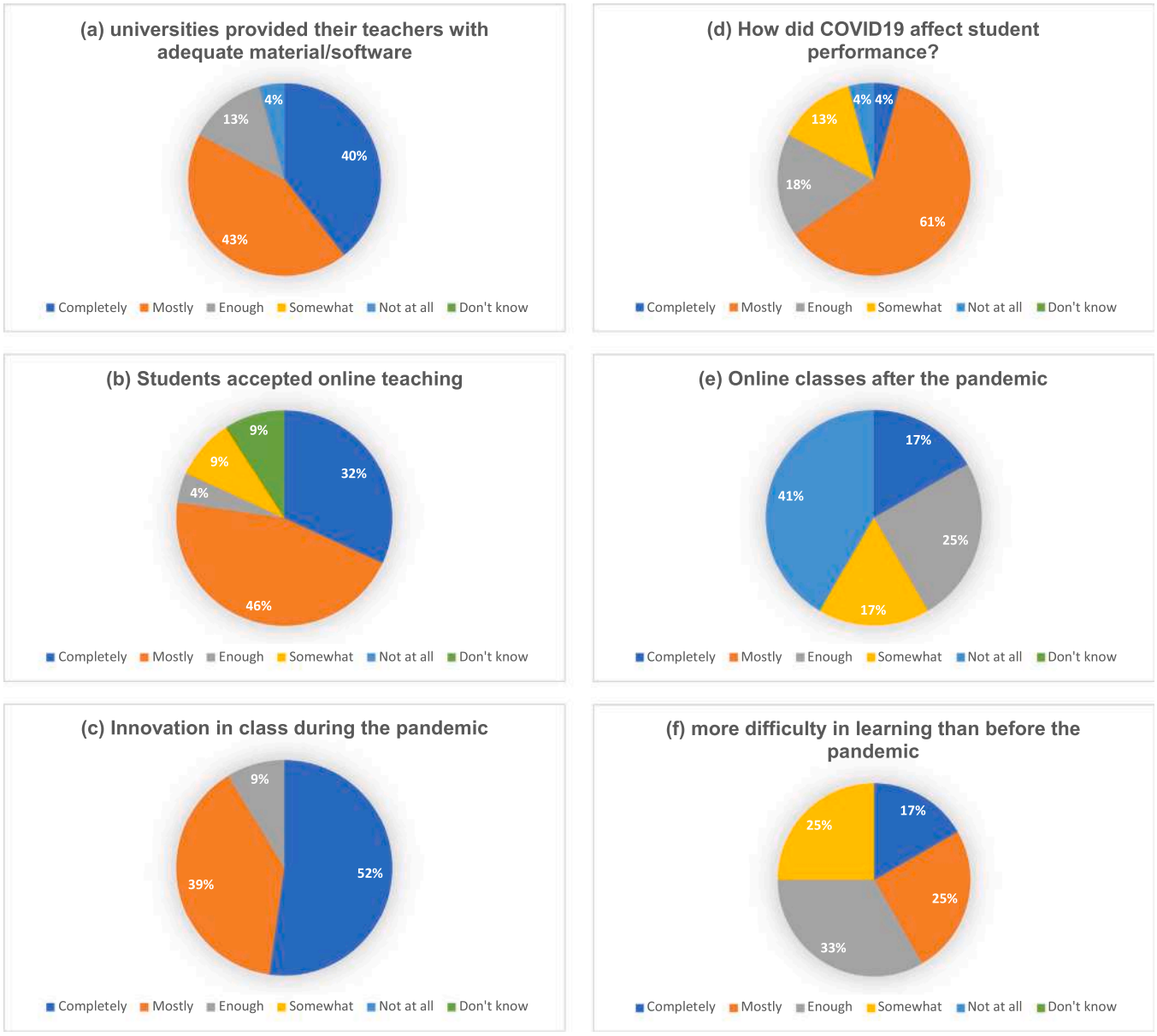

Fig. 13. Teaching situation during the months of COVID-19 lock down.

higher than 8.0. This indicates that, in the SMEs, students work in jobs that are not related to chemical engineering or that require a lower qualification.

With regard to the labour market for chemical engineering graduates, it should be noted that the Spanish Public Employment Services Servicio Público de Empleo Estatal (SEPE) registered a total of 960 contracts during the last twelve months (September 2022), against a total of 659 people seeking employment in this field. By age bracket, it can be observed that those applicants aged between 30 and 39 have a higher probability of finding a job, since during all the months of 2022 this was the age bracket with the highest number of contracts signed, exceeding 45% of all age brackets. The least demanded age bracket is that from 18 to 24 years. The Spanish job market for chemical engineers in 2022 (January-September) does not distinguish between genders, as the number of contracts for women and men is similar.

The types of jobs held by chemical engineers vary enormously (Fig. 12), with teaching in the different types accounting for 18%, together with the category of chemical engineer with an annual average of 17%, although these percentages vary above all in the month of September, where the occupation most employed is that of secondary school teacher, which increases to 25% due to the recruitment of teachers at the beginning of the academic year. Madrid is the Spanish province with the most contracts for chemical engineering graduates.

9. Teaching chemical engineering degrees during the pandemic

As we know, the academic years 19–20 and 20–21 were marked by the pandemic that affected the teaching of chemical engineering degrees due to the months of lock down. Teaching in most universities moved online via platforms such as TEAMs, Skype, etc. In order to find out how COVID-19 changed teaching, the first question asked was whether the university had provided adequate material/software to allow online classes to be held.

The answers to this question were that all the universities provided their teachers with adequate material/software for teaching online classes, as shown in Fig. 13a.

This situation affected not only the teachers, who had to adapt their materials to the new situation, but also the pupils, as the learning

methodology had also changed. A number of very general questions were asked of the teachers regarding this aspect in order to find out, through their experience, what their perception of teaching under these circumstances had been.

The first question was how the students had accepted online teaching and in this respect, it seems that the students were not adverse to it, as they are used to new technologies, since the majority of answers were somewhat in agreement or totally in agreement (Fig. 13b).

During this period, the lecturers had to adapt their materials to the new methodology, prepare their presentations so that they would be appropriate and easy for the student to follow. The majority of lecturers had to innovate in their teaching during the pandemic as reflected in the responses to the question about whether they innovated in their classroom teaching during the pandemic (Fig. 13c).

However, it seems that, despite the effort, and although the students adapted quite well to this type of teaching, they are not able to get the most out of the classes. It is quite possible that, although the teachers tried to quickly adapt their teaching, it is very difficult to hold the attention of a listener through a screen and even more so with class formats of over an hour in length in which the students lost focus during the sessions, with the loss of time and effort that this entailed. Performance clearly dropped and this is the overwhelming response from lecturers (Fig. 13d).

After pandemic situation, online classes at Spanish universities are not maintained, and students prefer their classes in classroom, although they demand online classes when they cannot attend a class (Fig. 13e). The most teachers currently think students have more difficulty in their learning (Fig. 13f).

But now the pandemic is over, teaching on chemical engineering degrees has returned to normal and must be continually improved so that our students can become professionals who can serve society in the future.

10. Conclusions

In conclusion, it should be noted that the chemical engineering degree in Spain enables the profession of Industrial Technical Engineer, which gives it great visibility in the employment market. The chemical engineering studies were designed under the guidelines of the CODDIQ (Conference of Directors and Deans of Chemical Engineering. www.coddiq.es), which represents a guarantee to adequately cover the training objectives at a degree level of modern engineering, in line with the quality standards demanded by different international professional associations such as FEANI (Fédération Européenne d'Associations Nationales dIngénieurs. www.feani.org), IChemE (Institution of Chemical Engineers www.icheme.org), and the EFCE (European Federation of Chemical Engineering www.efce.info).

The chemical engineering degree shows a positive evolution as an offer and with great competition from other studies. It continues to grow in the enrolment rate and cut-off grade. The degree in chemical engineering also grows in the demand, although in this section it is still far from finally having a quality cohort.

In the results section, it should be noted that the difficulties suffered by the pandemic will be reflected in the evolution of efficiency and performance rates, although the self-efficacy rate, which is the perception of graduates about the level of their training for getting a job is good.

In addition, in this section work must continue to improve initial dropout rates, especially that of graduation executing actions that improve these indicators.

The general satisfaction with the management and the quality of the training given and received by all the agents involved show an enormous strength in the degree.

The future offers an opportunity to keep on improving these studies and although the known challenges ahead are many, there is no doubt that chemical engineering degree will enhance as a result of working together to face common challenges.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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