Introduction

The global space sector is rapidly expanding in spite of a turbulent technological context and a more challenging environment. With the fourth largest worldwide presence, the European space sector stands out for its efficiency and competitiveness, seeing the emergence of an extensive number of entities conducting space activities in both public and private realms [1].

The Joint EU/ESA Statement for the future of Europe in space remarked that the goals to maintain a world-class European space sector must be supported by "an environment of outstanding education and skills and a thorough knowledge base" [2]. However, as more space industries choose Europe to establish, whether these are start-ups or well-known companies looking to expand their facilities, the space trends evolve while the space academic offer remains unchanged.

The main aim of this report is to provide a mapping of the skills that the renewed European space industry encourages recent graduates to have, against the knowledge acquired studying an engineering master's degree. In consonance with these goals, the report more specifically intends to:

- Review the current space engineering curriculum in European universities at graduate level and the additional skills achieved in these courses.
- Identify the European space industry needs and areas of expertise, as well as further qualifications that entry level engineers should have already obtained.
- Set up a framework for contrasting the information, and address key steps for accomplishing an education in line with the business demands.

Methodology

The space sector review performed in this study is divided in two categories: 1) the analysis of the courses offered in different European universities, and 2) the identification of the European industries' needs when hiring entry level engineers.

Space related education can be found in universities located all over Europe. The study focuses specifically on space engineering studies, analysing what is the graduate educational offer in different European universities. To do so, the Spanish Aerospace Technology Platform (PAE) proposes a Space Taxonomy [3] which classifies the different space areas into four branches: Research and Technology, Segments of Activity, Solutions for Society, and Space and Society. The identified graduate studies are evaluated against this taxonomy in terms of curriculum and additional competences.

On the one hand, in order to evaluate the master's curriculum, the Research and Technology branch is used. This branch covers the building matter, how things are done, and is itself divided into fifteen subsections enclosing the different space engineering areas seen in Figure 1. For this analysis, only the learning courses are considered, therefore excluding from the study both master's thesis and industry internships. Depending on each course's contents, these are classified according to the taxonomy's subsections. As for the optional modules, for the course distribution it is assumed that the students are equally allocated.

The remaining branches are evaluated for each master's degree by checking for quality accreditations and audits. As for the accreditation, the EUR-ACE® label certificate [4] can be considered the highest quality assurance system, since this encompasses a framework for identifying high-quality engineering degree programmes in European universities, being internationally recognized. After verifying which universities hold the EUR-ACE® certificate in their space engineering master's degree, a research is performed for the rest of institutions to verify if the master's degrees hold other type of accreditations or perform regular university's internal audits to check that a certain level of quality is maintained.

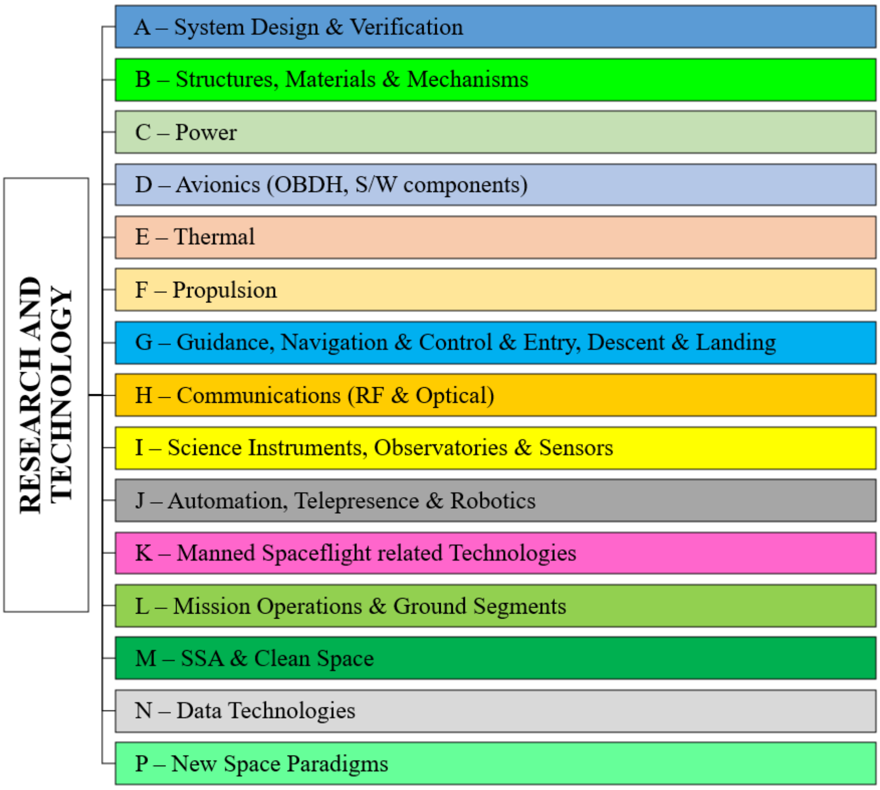

Figure 1. Research and Technology subsections [3].

On the other hand, in regard to the space industry, this represents one of the growing sectors in Europe. Total employment, measured in Full Time Equivalents (FTE), in the European space industry increased 3.9% from 2017 to 2019 [5]. This growth raises the question of what these companies look for in their employees both from their academic background and their interpersonal skills.

Knowing how the European industries are distributed in different space branches (i.e., materials, propulsion, AOCS, etc.), will allow an estimation of what the educational needs for the different Space Engineering master's degrees are. For example, if there is a larger percentage of space propulsion industries than of thermal systems, the probability that a recent graduate ends up working for the first one is higher, therefore existing a greater demand on space engineers with propulsion knowledge. With this data, the curriculum of the different space engineering master's degrees could be updated to follow the current European industry trends.

It is interesting to identify also what the industries are currently missing on their employees, or which personal profiles the people working in human resources encounter the hardest to find. This information can not only help with the master's curriculum but also with the additional competences that an engineer should have obtained upon graduation. A degree holding an EUR-ACE® label ensures certain programme outcomes, defining the interpersonal skills that the graduates must obtain. The study aims at double checking if these skills are what the space industry wants, or if there is something missing that should be added to the master's competences.

Data and Results

A total of twenty-seven master's degrees offered in eleven different European countries are evaluated. For the study, each programme's learning courses are classified depending on their contents within the different categories of the selected taxonomy. Afterwards, the courses are given a magnitude on the programme: the core modules are weighted with a 1, while for the optative modules, their weight comprises the fraction of the optative European Credit Transfer and Accumulation System (ECTS) that must be selected and the total offered. Finally, each taxonomy's subsection percentage is calculated with the course's weight multiplied by its ECTS.

With this, it is possible to obtain the percentage that each space engineering branch, according to those mentioned in Figure 1, has in European universities. This is obtained for each country, and for the overall European continent. A summary of the master's degrees included in the study can be seen below, on Table 1, where the different graduate degrees are distributed according to the country where they are taught. It is interesting noticing that the countries offering a larger number of master's programmes coincide with the European countries with higher space industry employment: France, Germany, Italy, Spain, UK, and Belgium. These six countries provided 90% of the European space capabilities in the year 2019 [5].

The data obtained from the analysis can be seen on the graphs below. On the one hand, Figure 2 represents the distribution of the knowledge areas taught at a graduate level. In other words, what percentage each taxonomy area has on the total of ECTS taught amongst all the universities included in the study. On the other hand, Figure 3 represents the same taxonomy percentages but separated for each country. This can also be seen in Figure 4, where the share that each European country has to these results is shown. This means, from the percentages obtained for each taxonomy level, how much each country is contributing with their graduate degrees.

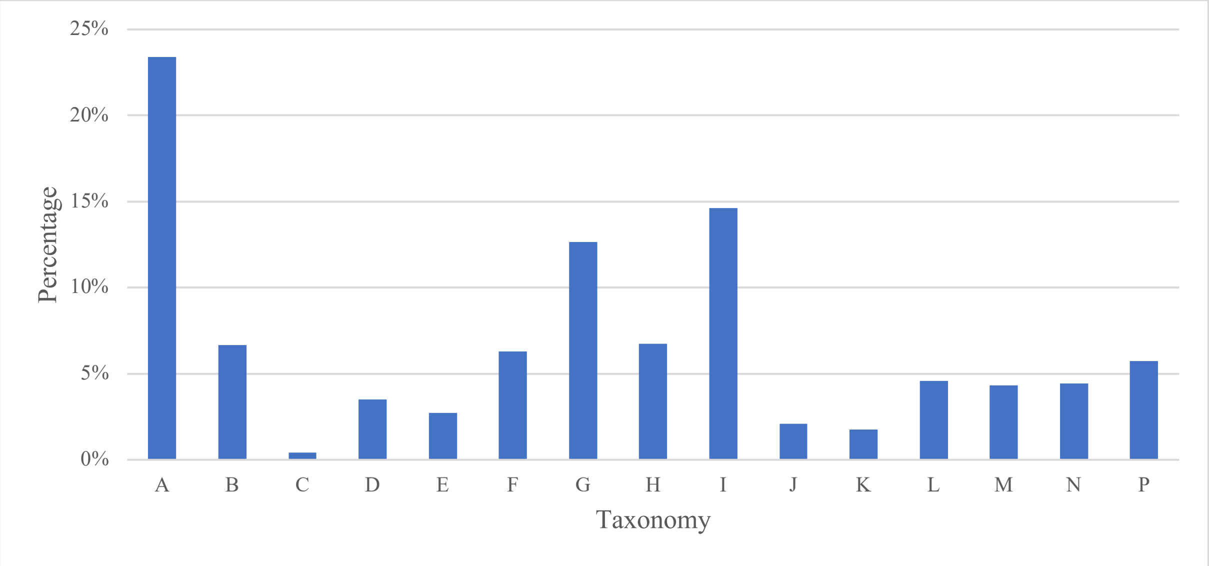

Figure 2. Space Engineering learning outcomes in European universities.

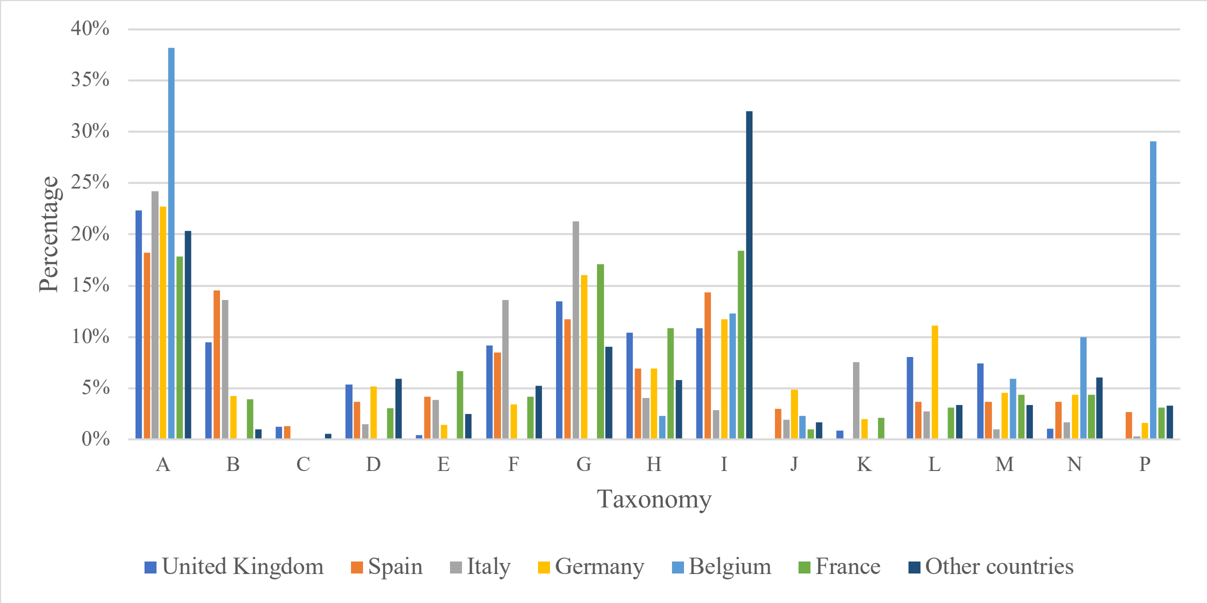

Figure 3. Space Engineering learning outcomes separated by country.

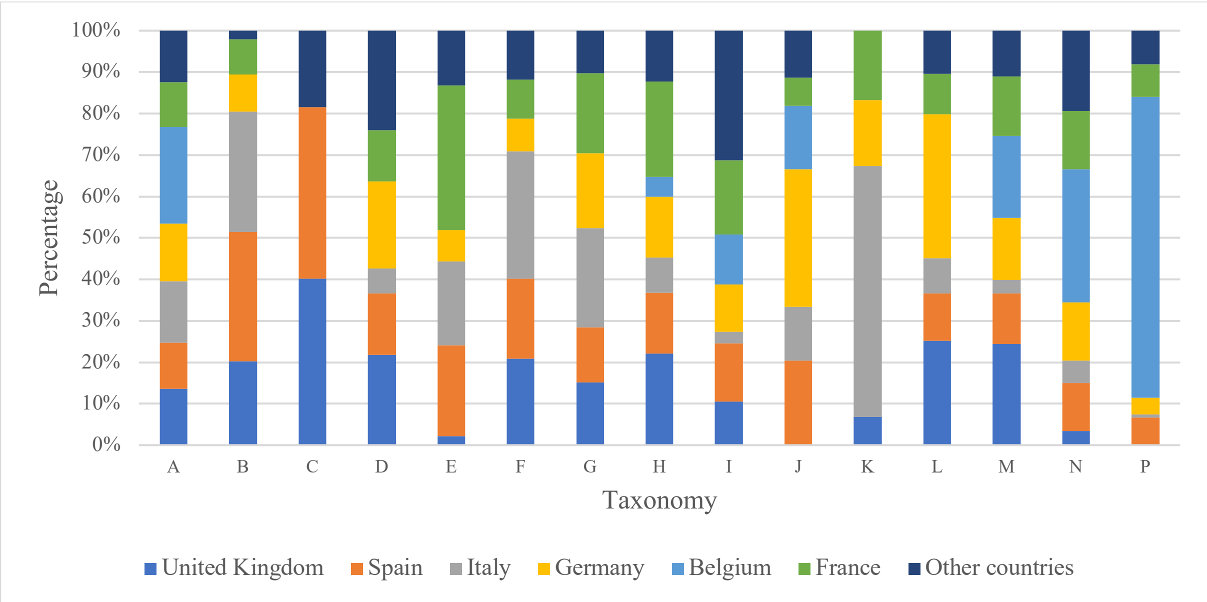

Figure 4. Countries' contribution to total Space Engineering learning outcomes in European universities.

It is worth noting some interesting results: the largest percentage is observed on (A) System Design & Verification, which is similarly distributed amongst the countries, and shows the importance that systems engineering is given in the European space engineering education. Followed by (I) Science Instruments, Observatories & Sensors, this reveals Europe's universities largest concern on the overall space picture rather than focusing on the different subsystems. Also, there is not a large percentage of (K) Manned Spaceflight and Related Technologies courses, which may be due to Europe not being a big astronaut exporting continent. Finally, Belgium has the largest contribution to (P) New Space Paradigms, which can be explained with ESA's European Space Security and Education Centre (ESEC) located there.

The classification of the courses into the PAE taxonomy allows the organization and comparison of the different evaluated universities around Europe. The results obtained have revealed how universities located in different countries focus on different fields of the taxonomy. The PAE taxonomy used for this study was evaluated in Spain, however, each university may use a different classification to assess their courses, as ESA's Technology Tree [6] or NASA Technology Taxonomy [7]. Regarding these, the ESA taxonomy features 26 technology domains which provide a classification of all technological activities within the space agency. However, this taxonomy has been poorly updated since its release in 2003, and mostly focuses on ESA's offices rather than in the space industry advance. On the other hand, the NASA Technology Taxonomy includes 17 levels that also encompasses aviation topics – i.e. (TX 16) Air Traffic Management and Range Tracking Systems – and has a stronger focus on human space exploration, mostly avoided by ESA.

The existence of these other taxonomies explains the different percentages obtained amongst the PAE levels, since not all graduate studies are based on the same approach. Universities whose studies are based on ESA's Technology Tree may have more percentage of courses dedicated to space science and spacecraft subsystems while those based on NASA's taxonomy may dedicate more courses to the human element in space.

Table 1. List of Universities [8-34].

Country	University	Programme	EUR-ACE®	Other accreditations
UK	Cranfield University	MSc in Astronautics and Space Engineering	No	Royal Aeronautical Society (RAeS)
	University of Surrey	MSc in Space Engineering	No	The Institution of Engineering and Technology
	University of Leicester	MSc in Space Exploration Systems	No	University Quality Assurance Team*
	University of Southampton	MSc in Space Systems Engineering	Yes	-
	University College London	Space Science and Engineering: Space Technology MSc	No	N/A
Spain	Universidad Carlos III de Madrid	Master in Space Engineering	No	SGIC-UC3M*
	Universitat Politècnica de Catalunya	Master's Degree in Space and Aeronautical Engineering (Space track)	No	AQU Catalunya (EQAR)
	Universidad Politécnica de Madrid	Master's Degree in Space Systems	No	ANECA
	Universidad de Alcalá	Master's Degree in Science and Technology from Space	No	SICAM
	Universidad del Pais Vasco	Master's Degree in Space Science and Technology	No	ANECA/UNIBASQ
Italy	Politecnico di Milano	Master in Space Engineering	Overdue	N/A
	Sapienza University of Rome	Master Course in Space and Astronautical Engineering	Yes	-
	Politecnico di Torino	Specialising Master in Space Exploration and Development Systems	No	N/A
	University of Pisa	Master of Space Engineering	No	N/A
Germany	TU Berlin	MSc in Space Engineering	No	N/A
	Julius-Maximilians-Universität Würzburg	Master's in Satellite Technology - Advanced Space Systems	No	Elite Network of Bavaria
	TU Munich	Earth Oriented Space Science and Technology	No	N/A
	University of Bremen	MSc in Space Engineering	No	FB4*
Belgium	Ghent University	MSc in Space Studies	No	Ghent Quality Assurance*

* University internal quality assurance system.

	KU Leuven	MSc in Space Studies	No	COBRA*
France	PSL Université Paris	Master in Space Science and Technology (Astronomical and Space-based Systems Engineering track)	No	N/A
	ISAE-SUPAERO	Advanced Master Space Systems Engineering (TAS Astro)	No	N/A
Netherlands	TU Delft	MSc in Aerospace Engineering (Space Engineering track)	No	NVAO
Denmark	Technical University of Denmark	MSc in Earth and Space Physics and Engineering	No	N/A
Slovakia	Slovak University of Technology in Bratislava	MSc in Space Engineering	No	Accreditation Commission of the Government of the Slovak Republic
Ireland	University College Dublin	MSc in Space Science and Technology	No	N/A
Sweden	Luleå University of Technology	MSc in Space Science and Technology (Space Technology and Instrumentation track)	No	Head of unit at the unit for education and research*

* University internal quality assurance system.

As for the review of the additional competences, while the majority of the degrees analysed had an accreditation either from an internal university commission or an external certifying body, just three of them hold an EUR- ACE® label – including one that is overdue. Although this certification is pivotal for promoting the quality and international renown of the degrees, most universities opt to audit their courses with national industries or accrediting bodies. The certification obtained in these cases is equally valid, however, it lacks the common framework that the EUR- ACE® label intends to provide. Moreover, it is also worth noticing that many universities do not have any published data on their quality assurance systems. Therefore, it is inconclusive whether these master's degrees do not hold any accreditation nor have any quality guarantees, or the data is private.

On the other hand, in front of the lack of resources to gather the needed information from aerospace companies, in order to complete the study, an exhaustive list of more than 300 (three hundred) European space companies has been obtained [35, 36]. These companies are classified according to their major areas of expertise into the taxonomy levels aforementioned in Figure 1, following a similar procedure as the one used for allocating the learning courses. The companies' distribution in Europe is obtained, presenting a way of mapping the most accessible fields in the European space industry against the different areas taught in postgraduate courses. This comparison allows the understanding of which are the space departments recent graduates are most likely to work for, and to review if the taught courses are in line with these results.

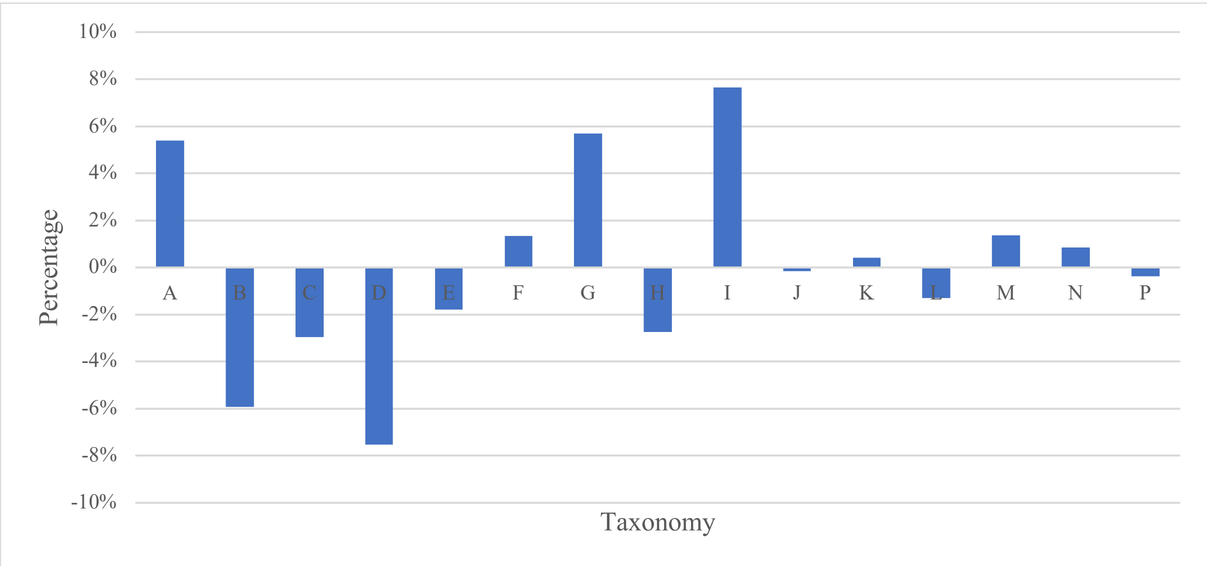

Figure 5. Difference of distribution between industry and studies.

Figure 5 pictures the difference obtained from each space area's percentage taught in university with the one needed in the European industry. Although most of these have quite similar results, the most pivotal outcome to remark is the lack of resources in (D) Avionics and (B) Structures, Materials & Mechanisms, while there is a surplus of courses focused on (I) Science Instruments, Observatories & Sensors. These results prove how the European space industry evolved, focusing more on software and electronics, as well as new materials for space, while the courses taught are outdated, concentrating on the space science and observation rather than on the new trends.

The study outcomes can be compared with the ones obtained by the UK Space Agency in their 2020 Space Sector Skills Survey [37]. Here, the 52% of UK businesses reported having limitations hiring engineers specialized in software, followed by the 48% reporting lack of radio frequency engineers – which would be enclosed in (H) Communications – also with a negative percentage in Figure 5. Hence, there is a certain similarity when comparing UK's space industry knowledge demands with those obtained from the industry's areas of expertise for all of Europe. Moreover, PAE also has a classification for the space activity in Spain [38]. When comparing these percentages with the taught courses in Spanish universities, the segment (B) Structures, Materials & Mechanisms is the one with the highest lack of resources, followed by (D) Avionics, while the one with the greatest surplus is (I) Science Instruments, Observatories & Sensors. These results are again very similar when compared to the ones obtained in Figure 5 for all Europe.

Lastly, when trying to attain which are the transversal skills that would thrill a human resources' team, more difficulties arise. A first option to collect this data was to look at current job offers, however, with the different trends continuously changing, this was not considered a valid approach. In order to attain what are the additional competences that industries demand, the UK Space Sector Skills Survey [37] was used as the main source of information.

In the survey findings, it can be observed how the 67% of space industries reported having skill gaps in project management, followed by the 48% reporting lack of teamworking and managing interpersonal relationships, and the 43% finding limitations in leadership or motivational skills, business planning, and client management skills. These skill gaps can be compared with the CDIO (conceiving-designing-implementing-operating) syllabus [39], which intend to set a detailed learning outcome for personal and interpersonal skills in engineering courses. This syllabus is organized into four levels with their corresponding subsections, which can be seen in Figure 6. Here, it is interesting to observe how while teamwork and business context are included, there is no reference to project management – the most missed skill – or leadership.

1. Disciplinary knowledge and reasoning.	**2. Personal and professional skills and attributes.**	**3. Interpersonal skills: teamwork and communication.**	**4. Conceiving, designing, implementing, and operating systems in the enterprise, societal and environmental context.**
1.1. Knowledge of underlying mathematics and science. 1.2. Core fundamental knowledge of engineering. 1.3. Advanced engineering fundamental knowledge, methods and tools.	2.1. Analytical reasoning and problem solving. 2.2. Experimentation, investigation and knowledge discovery. 2.3. System thinking. 2.4. Attitudes, though and learning. 2.5. Ethics, equity and other responsibilities.	3.1. Teamwork. 3.2. Communications. 3.3. Communications in foreign languages.	4.1. External, societal and environmental context. 4.2. Enterprise and business context. 4.3. Conceiving, systems engineering and management. 4.4. Designing. 4.5. Implementing. 4.6. Operating.

Figure 6. CDIO Syllabus v2.0 at the Second Level of Detail [39].

These results show how an update on the transversal skills reached at a graduate level in European universities is necessary to catch up with the business demands for new graduates. Although some of the master's degrees analyzed had courses in Space Project Management, it is pivotal that universities keep promoting these types of subjects, as well as group projects where students can exercise interpersonal relationships, leadership, and business plans.

Conclusion

This paper followed a new approach to identify the gaps between the European space education and the capabilities demanded by the industry.

Firstly, the universities' courses were analysed. The results obtained represent a first approach to bring together to the same framework all the space education in Europe, being able to compare the knowledge and competences earned. It was followed by an evaluation of the European space industry. In this part, the proposed methodology also introduced the same taxonomy scheme, allowing the correlation with the academic results in order to identify the disparities.

The main outcome of this paper is therefore the introduction of a common foundation to assess the space sector in Europe, both in universities and companies. This allows each entity to analyse and contrast their data with that of the other bodies, helping in their plan of action. The goal of a shared European standard is to advance towards an updated and more efficient European space sector.

However, the first results are just an overview of a possible common framework using non-exhaustive data. In order to accomplish all the goals, and help universities adapt to the industry needs, some further steps should be taken: first, the PAE taxonomy model should be exported to Europe, having a global system in the continent which will allow to catalogue all at once the technical space data. As a second step, participation from European space companies will be necessary. A survey could be created in order to allow companies to identify their areas of expertise according to the selected taxonomy, and to describe the additional competences their employees must have. This way, the industry data will be broader and more trustworthy.

Nevertheless, while it is true that the companies' data was not thorough and further information would be necessary to complete the study, the results obtained demonstrate the urge to update the universities' curriculum in order to adapt to the contemporary space trends. Therefore, the last step will be that European universities offering space studies review their curriculum so as to comply with the acquired data from the space industry. With this, new space graduates will not only have solid foundations on the most relevant topics, but also have the necessary interpersonal skills for starting their career.

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