Comprehensive map of completed and ongoing programmes addressing curricula in the bio-based sector

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Content

1. Introduction

This report is the result of the study carried out by the UrBIOfuture consortium to provide a map of completed and ongoing programmes addressing curricula that involve bio-based activities will be developed in a wide range of educational levels and covering a wide geographical scope in the EU.

This mapping exercise is required in order to have the overall picture of current European educational offer in bio-based activities at various levels. To do so, a preliminary step was conducted in order to define a transversal methodology and terminology for the identification of needs and competences (professional profile) as they allow raising the profile of career opportunities in the bio-based industry and related academic fields.

The methodology section describes the design of this study, its tools and criteria to provide the best possible description of the current educational system addressing bio-based curricula at the four different levels: VET, Undergraduate, Master and PhD.

The results are presented by fields, competences and sub-competences in order to provide a better understanding of the current educational supply of bio-industry professionals. All graphs are represented in percentages, providing a visual aid to help understand, identify and allow for a comprehensive overview of the different academic bio-based programmes, their lacks and priorities.

2. Methodology

The methodology explained below has been designed to enable the assessment of curricula across the different educational levels to analyse whether they address certain competences identified as important for the bio-economy in 2030. The following steps have been followed:

1) Identification of competences at previous UrBIOfuture's activities: Focus Group method, Dynamic Workshop, Strategic bio-based reports and documents.
2) Educational Programmes assessment using EPT tool described below.
3) Analysis of programmes grouped per educational level to show the results of the assessment.

2.1. Educational Programmes Template (EPT)

The **Educational Programmes Template** (EPT) is the tool designed to gather all the relevant data from the analysis of the educational programmes (see complete document on Annex 5.3)

The **template is a qualitative instrument**. However, it has been considered necessary to close the answer options to a good extent, although there is room for additional open questions that will be very significant for the analysis. The template allows for gathering information on educational programmes developed at the different educational levels: VET, Undergraduate, Master's Degree and PhD. The document's structure allows for the identification of both, on the one hand, basic information on the educational programme that is object of the analysis and, on the other hand, to compile information on the competences and contents that they address in their development. A set of general and specific competences was defined following the guidelines and results of the Focus Group Report, the Dynamic Workshop as well as the main R&D&I areas to support bio-based value chains in Europe" from the "STRATEGIC INNOVATION & RESEARCH AGENDA (SIRA) - BIO-BASED INDUSTRIES for Development & Growth in Europe – May 2017 (https://www.bbi-europe.eu/sites/default/files/sira-2017.pdf). Moreover, the items to be informed in the EPT are cross-referenced with the Industrial Survey so that the data will be comparable and the analysis will allow for identifying existing gaps and mismatches between industrial needs and current training offer available in Europe.

1. Objective

The objective of the template is to compile information on the educational programmes implemented at the different educational levels in order to draw a general map that will allow for the identification of the training offer linked to the bio-based industrial sector which is being offered in the European context.

2. Language

The template is produced in English and the data will be also informed in English to facilitate the availability of the data to the general public.

3. Participants

The template is an instrument designed to be used internally by the project partners. Thus, partners will complete the data from the analysis of the information from the educational programmes available on the different institutional websites of universities, VET centres or educational administrations.

4. Implementation

Firstly, the National Education System EURYDICE developed by the EU was used to look for the different countries' official education websites.

To reduce the number of existing educational programmes trying to capture all the relevant programmes, entities being members of the European Bio- based economy Alliance (EUBA) (https://bioeconomyalliance.eu/about-euba-bioeconomyalliance), and the BIC members (https://biconsortium.eu/membership/associate-members) were selected first. Additionally, the most relevant universities were identified in a google search using bio-based economy key words.

2.2 Guidelines to identify programmes

Target European countries (28) were distributed by partners (see Annex 5.1) and each partner had to select the most relevant programmes to be analysed according to a set of priorities and particularities that will be explained in this section.

Taking into account both the reality of national education systems and the national focusses that life science educational programmes have, the different countries presented considerable differences in their approach to professional education itineraries, which resulted in the implementation of particular adjustments in the selection of programmes by country (see Annex 5.5).

Once all the mapping data was gathered, an additional action was carried out to contribute to a meaningful analysis by discarding replicas, that is, when the exact same programme was offered at different educational institutions. Those duplicates were identified and removed using the Excel tool, i.e. any duplicated entries with all fields identical except for the following:

- Name of the Institution (University, National Agency, Institute, etc…)
- Website of the Institution
- Link to the Educational Programme

The original raw data collected included 1228 programme entries. However, after discarding duplicates (316), a total of 912 programmes were analysed.

The following steps were suggested to approach the selection of programmes:

1. Elaborate a **relevant educational programme excel file** with all the links of the most relevant educational programmes: having a complete list helps taking strategic decisions on the relevance of the different programmes, and on wisely managing the workload, adjusting the list accordingly. Secondly, this complete list will be used as a check list in order to know which educational programmes have been included and which have not. This will tell us the leading bio-based economical educational programmes ratio within the country (a percentage among programmes included and initial potential programmes, for instance).

   In order to identify educational programmes in the different countries, an adequate methodology should be implemented. The following table shows the criteria to be used in each case.

EDUCATIONAL LEVEL	SUGGESTIONS FOR A BETTER SEARCHING OF EDUCATIONAL PROGRAMMES
VET	Professional educational programmes focused on the development of technical skills
Undergraduate	To seek only those degrees approved by the Bologna Process and the European Higher Education Area, i.e. University degrees with 240 ECTS
	We recommend revising one representative university per Country Region, due to the huge number of Degrees a single University can offer, and seek for the university better align with the Bio-Based Industry.
	For a faster seeking, we propose to start using Universities belonging to Bio-based Industries Consortium as Associate Members. In regions with no university being BIC member search in google their activity in bio-economy (events, EU projects….)
	https://biconsortium.eu/membership/associate-members

Master	To seek only those degrees approved by the Bologna Process and the European Higher Education Area, i.e. Master degrees with 60 ECTS
	We recommend revising one representative university per Country Region, due to the huge number of Degrees a single University can offer, and seek for the university better align with the Bio-Based Industry.
	For a faster seeking, we propose to start using Universities belonging to Bio-based Industries Consortium as Associate Members. In regions with no university being BIC member search in google their activity in bio-economy (events, EU projects….)
	https://biconsortium.eu/membership/associate-members
PhD	We recommend revising one university per Country Region, due to the huge number of Degrees a single University can offer
	For a faster seeking, we propose to start using Universities belonging to Bio-based Industries Consortium as Associate Members. In regions with no university being BIC member search in google their activity in bio-economy (events, EU projects….)
	https://biconsortium.eu/membership/associate-members

2. Conduct an in-depth analysis of one of the programmes previously identified using the online template and controlling the time needed to do so.
3. Make an estimation of the needed time for completing the analysis of all the educational programmes included in the list.
4. If the estimated time exceeds the available one, set an order of priority within the list (following the recommendations explained before).
5. Conduct the in-depth analysis for the final selection of programmes using the online Template. All the information should be included in English. You may analyse educational programmes published in any other language if you can read them competently and informing the template in English.
6. As we will be able to access to much more information than the one foreseen in the template, please include it, as well as your thoughts and possible conclusions, in the relevant educational programmes excel file, in a “Remarks” column.

3. Results

3.1 Sample of Educational Programmes Analysed

The development of this phase of the study consisted of the analysis of 912 educational programmes at the levels of VET, Undergraduate, Master and PhD in the different member countries of the European Union, with the exception of Luxembourg and Greece, which have not been represented.

The following figure shows the distribution of the sample analysed across the different countries for which data have been obtained. Not all countries were analysed with the same intensity at all academic levels, due to the constraints explained in the above methodology section.

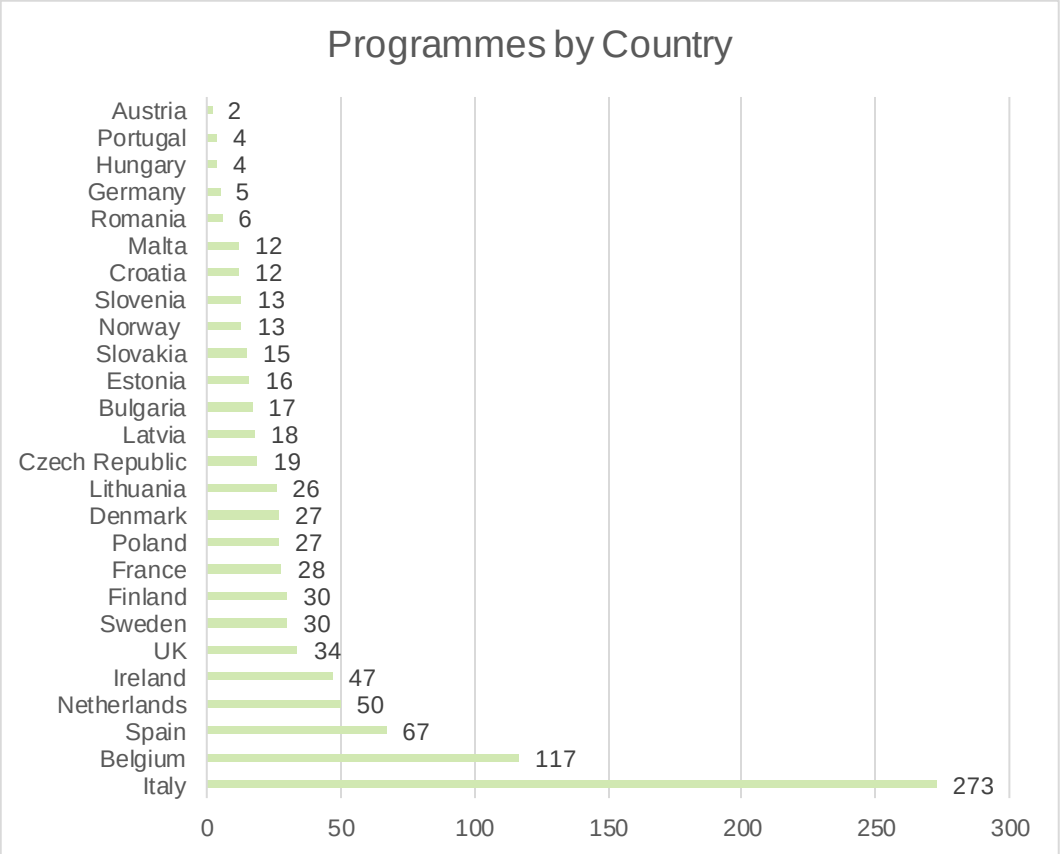


Figure 1: Total number of educational programmes per country

The unbalanced number of programmes across countries is also a result of the methodological constraints: not all countries educational institutions provide the same level of information regarding their educational offer and not all of them provide information in English or other languages known by the members of the consortium and the working group. Higher Education levels are the most commonly found in English whereas lower VET levels are usually found only in the local language. Therefore, the number of programmes represented for each country does not correlate with the actual number of existing programmes but with the availability of their information.

The following figure shows the percentage of educational programmes analysed according to the educational level at which they are taught. In total, 912 programmes have been analysed, distributed as follows: Master's (417); Undergraduate (316); PhD (111); and VET (68).

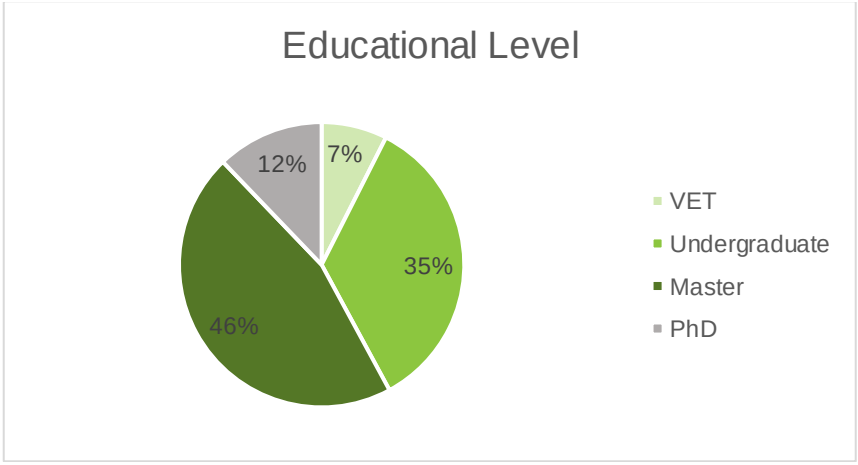


Figure 2: Distribution of programmes by educational level (in percentages)

In general terms, most relevant programmes related to bio-economy are identified at master's level (almost half of the sample), followed by undergraduate programmes across EU countries.

Below the distribution of the sample by countries at the four educational levels.

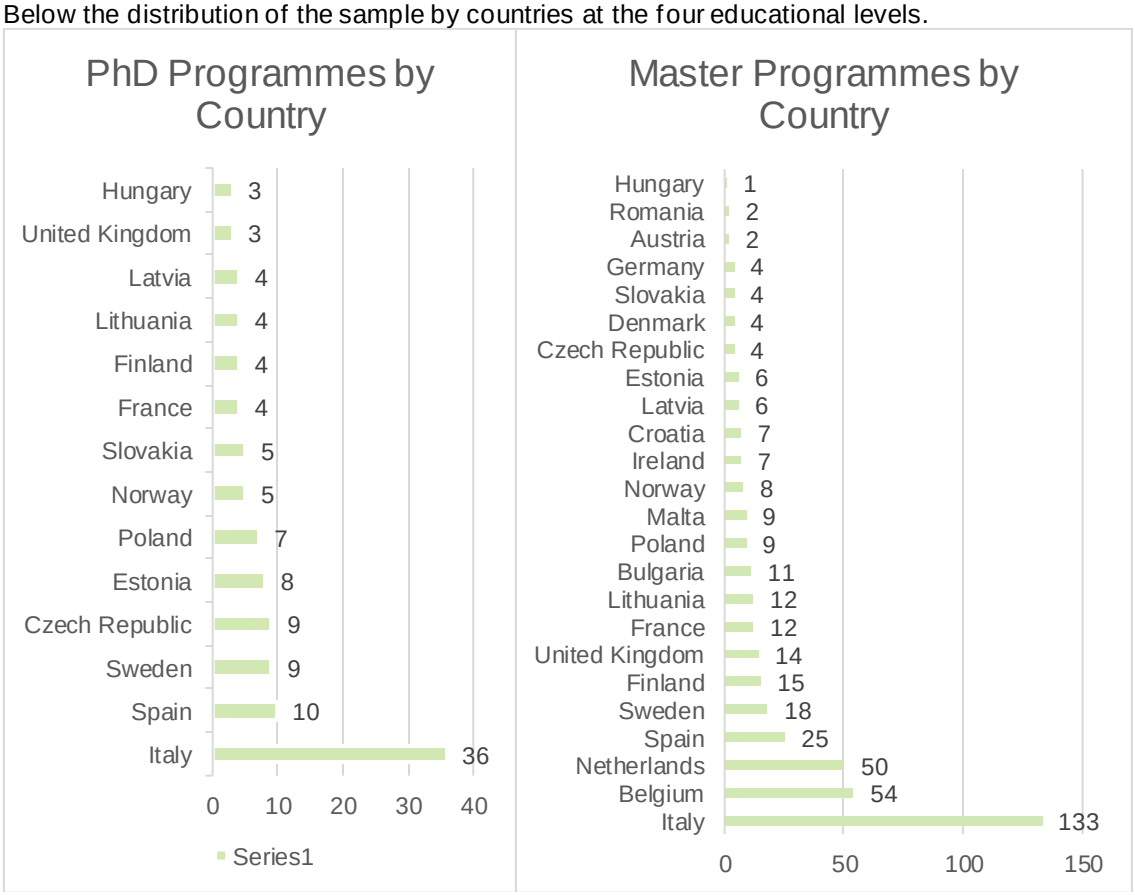


Figure 3: Number of PhD and Master's programmes by country

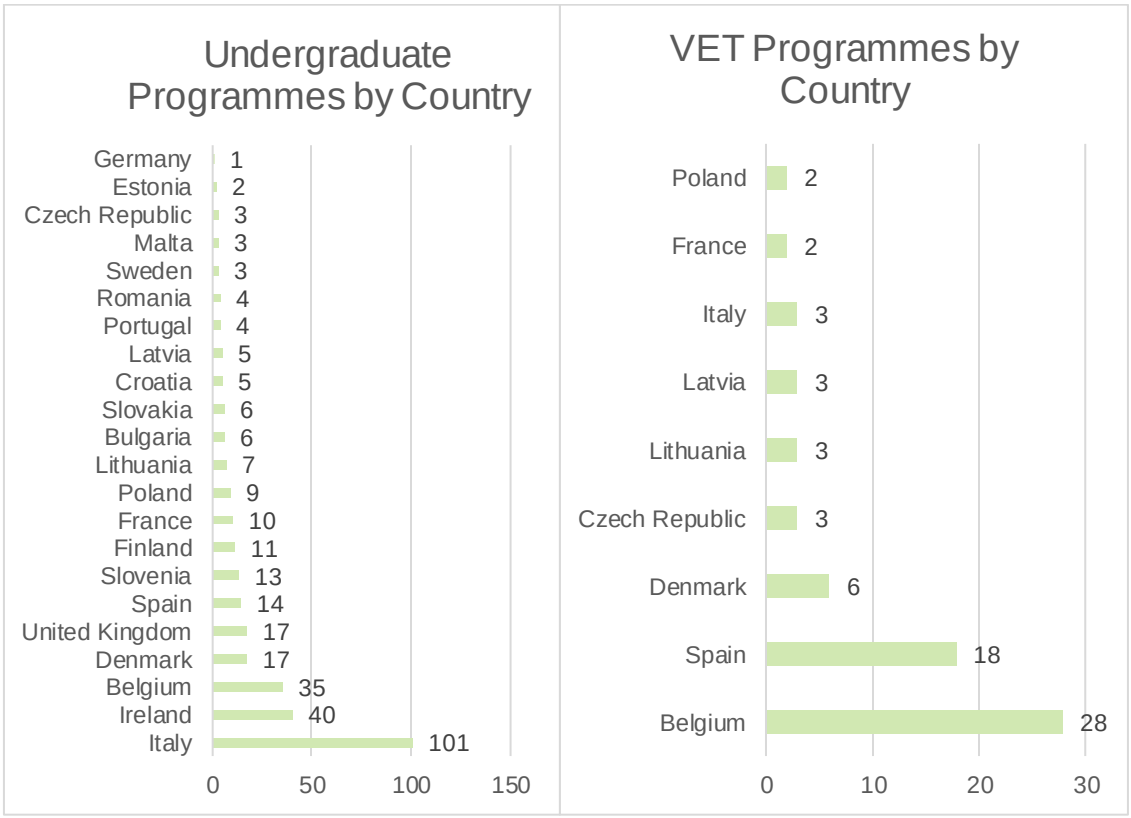


Figure 4: Number of Undergraduate and VET's programmes by country.

Figure 5 shows the distribution of the educational programmes (in percentages) analysed according to how they are implemented (on-site, online or blended-learning).

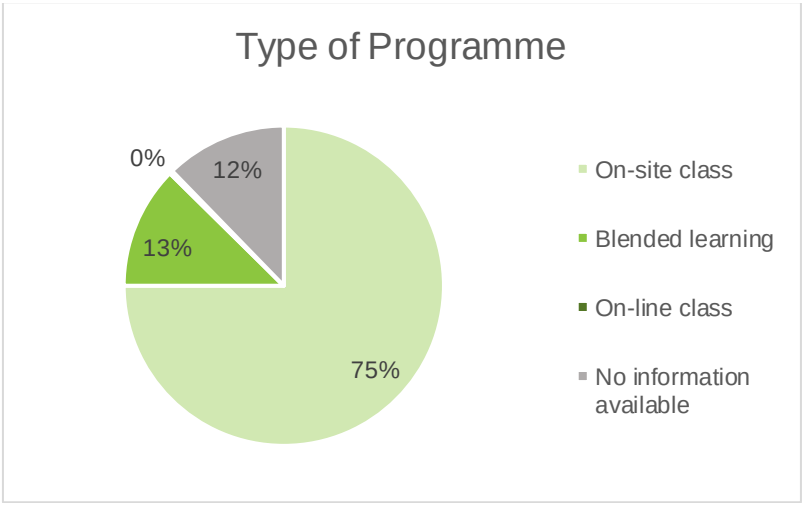


Figure 5: Distribution of programmes by type (in percentages)

Most programmes (75%) are taught in-class and only 12% of the total are identified as blended-learning (most significant at PhD level and almost insignificant at VET's) and for the same percentage (12%) no information was provided on the type of programme. On-line learning is barely represented and only at Master's level. Below the distribution of types of programmes by educational level. The percentages on the following figures are calculated taking into account the total number of programmes analysed at each educational level: 68 VET, 316 Undergraduate, 417 Master and 111 PhD.

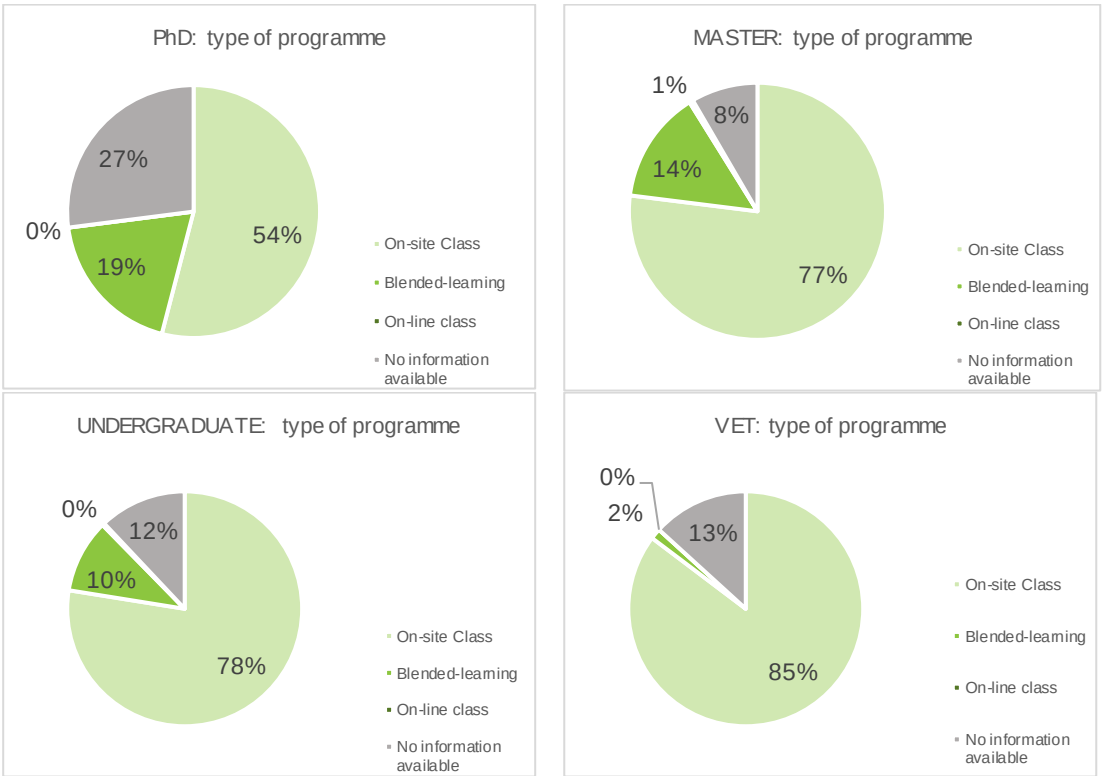
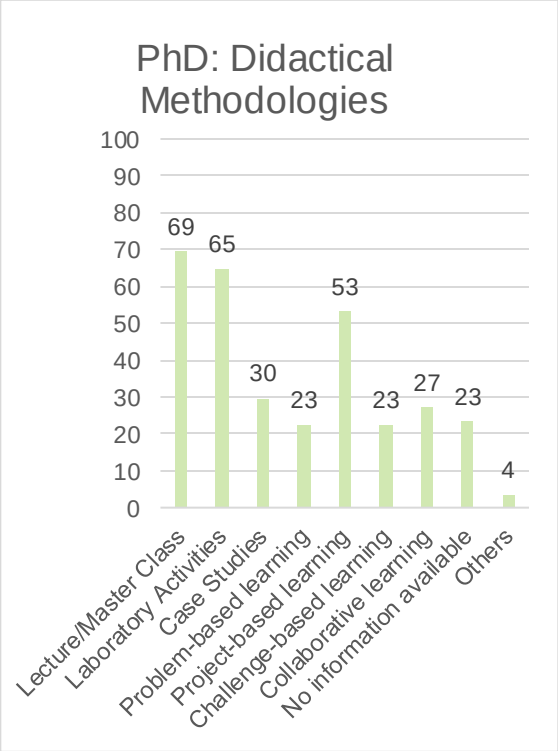
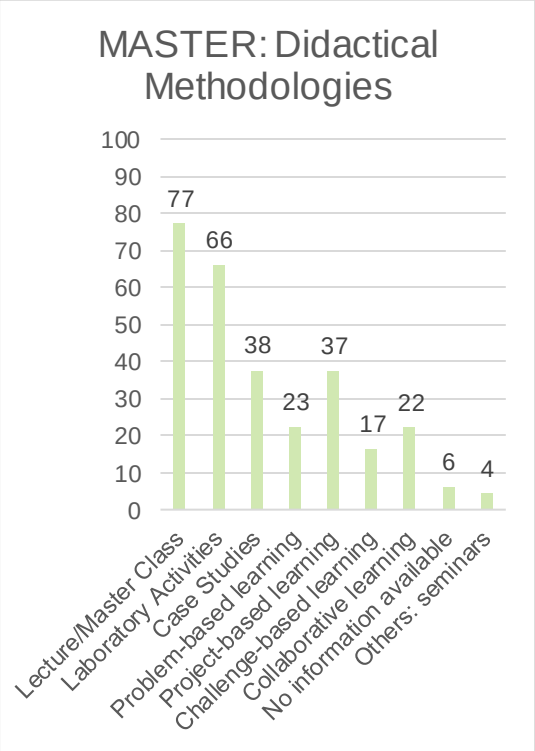


Figure 6: Distribution of programmes by type and educational level (in percentages)

3.2 Didactical Methodologies Implemented

When looking at didactical methodologies at the four educational levels, *Lecture/Master Class* is the clear winner across levels, followed by *Laboratory Activities and Project-based learning*. It should be noted that multiple answers were accepted in this section of the EPT, which allowed to represent the methodological variety in the different educational programmes, that is, it is very common to find more than one methodology in the implementation of the training activities within the same programme. The figures that represent these values show the percentage of programmes within each educational level that use each of the identified methodologies. The percentages on the following figures are calculated taking into account the total number of programmes analysed at each educational level: 68 VET, 316 Undergraduate, 417 Master and 111 PhD.





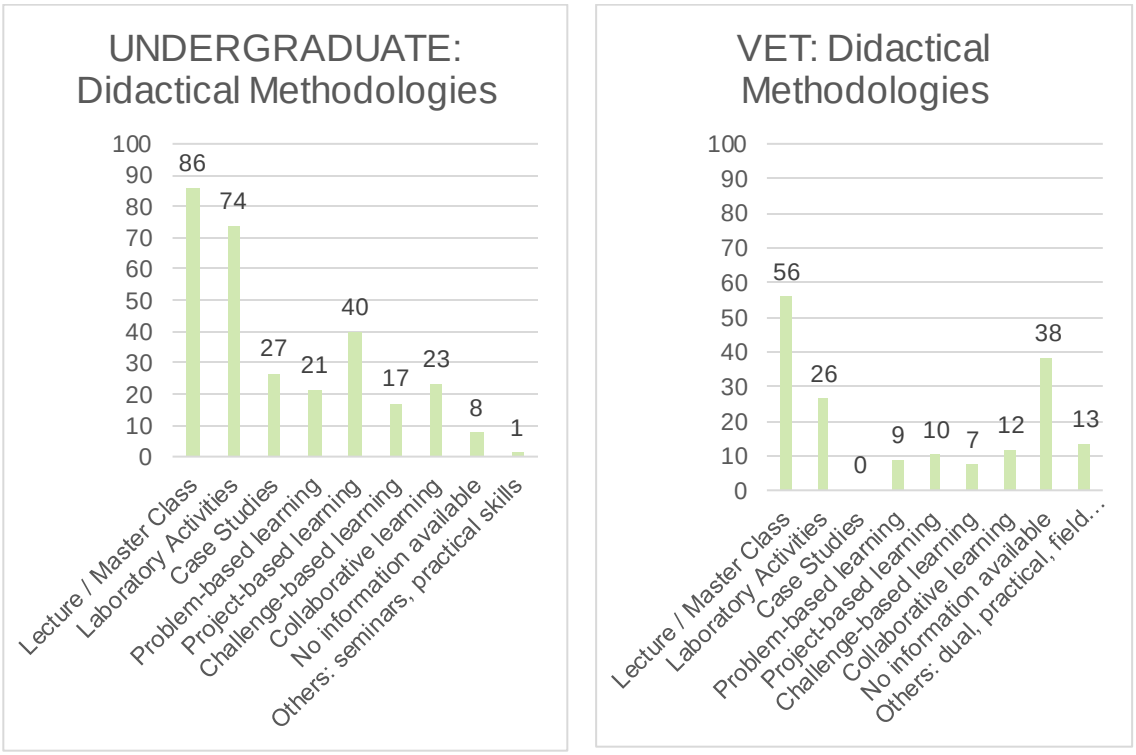


Figure 7: Didactical Methodologies at the four educational levels (in percentages).

A closer look at the PhD level reveals that activities are mainly carried out using a *master class methodology*, followed by *laboratory activities*, and *project-based learning*. *Case studies* and *collaborative learning* activities are significantly less represented.

The master programmes analysed show a similar trend to that of doctoral programs, with a high presence of *master-class*, followed by *laboratory activities* being followed by case studies and *project-based learning*.

The distribution of methodologies at the undergraduate level reveals a much greater concentration in the *master class*, followed by *laboratory activities*. Then, but at a considerable distance, follows *project-based learning* and, to a lesser extent, the rest of the methodologies.

VET´s emphasis on dual learning with strong involvement of industrial collaboration and practical field work seems to be another popular tendency in bio-economy related programmes.

3.3 Involvement of In-company Training Activities

More than half (55%) of the analysed programmes involve in-company training; at VET level it is even higher (75%). Only 10% on average do not include in-company training activities and for 35% of the programmes analysed no information is given about the latter.

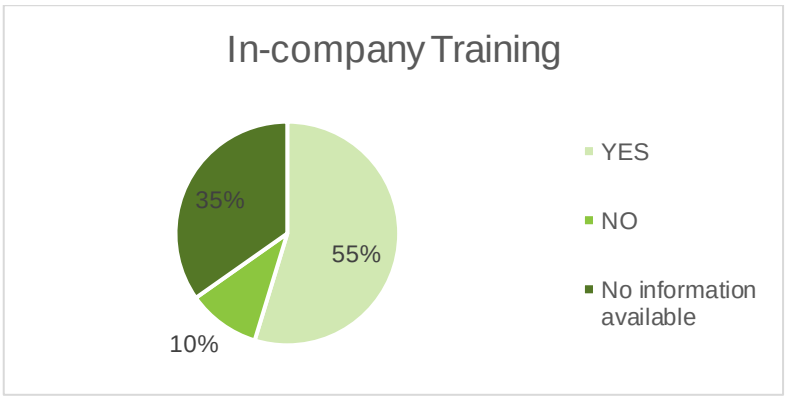


Figure 8: Distribution of programmes in relation to the involvement of in-company training.

The percentages on the following figures are calculated taking into account the total number of programmes analysed at each educational level: 68 VET, 316 Undergraduate, 417 Master and 111 PhD.

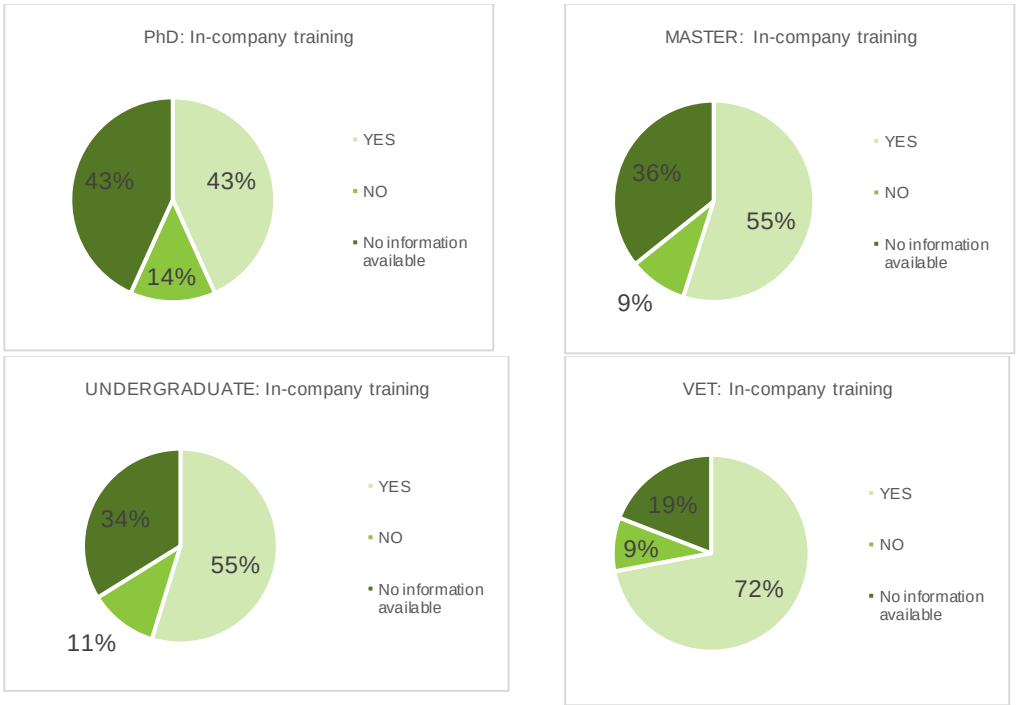


Figure 9: Distribution of programmes by educational level in relation to their involvement of in-company training activities (in percentages).

In the case of the doctoral programs analysed, although they do not include information on additional in-company training in most cases, it is worth mentioning that industrial doctoral programs exist. Although these are mostly structured as an agreement for collaboration between the university and the

3.4 Academic Fields (according to ESCO V1) [1]

Out of the 27 academic fields options (according to ESCO V1), the most represented academic fields are the following 6, consistently across all programmes, although distributed differently according to intensity at the four academic levels. There is also one slight change at VET level, were *Human health and social services activities* is less recurrent and outnumbered by *Transportation and storage* as represented below:

PhD: 1. - Scientific and Technical Activities (60%) 2. - Agriculture, Forestry and Fishery (56%) 3. - Chemical Industry (40%) 4. - Energy and water supply, sewerage and waste management (31%) 5. - Manufacturing of food, beverages and tobacco (24%) 6. - Human health and social services activities (24%)	Master: 1. - Chemical Industry (91%) 2. - Energy and water supply, sewerage and waste management (78%) 3. - Human health and social services activities (52%) 4. - Scientific and Technical Activities (48%) 5. - Agriculture, Forestry and Fishery (47%) 6. - Manufacturing of food, beverages and tobacco (34%)
Undergraduate: 1. - Agriculture, Forestry and Fishery (57%) 2. - Chemical Industry (45%) 3. - Manufacturing of food, beverages and tobacco (37%) 4. - Scientific and Technical Activities (31%) 5. - Human health and social services activities (30%) 6. - Energy and water supply, sewerage and waste management (30%)	VET: 1. - Agriculture, Forestry and Fishery (51%) 2. - Manufacturing of food, beverages and tobacco (35%) 3. - Chemical Industry (29%) 4. - Energy and water supply, sewerage and waste management (18%) 5. - Scientific and Technical Activities (12%) 6. - Transportation and storage (12%)

The academic fields represented in the relevant programmes analysed can be seen in figures 10 to 13. We should note that multiple options were possible in this section of the EPT, and often the same programme offers expertise in a variety of fields. The percentages on these figures are calculated taking into account the total number of programmes analysed at each educational level: 68 VET, 316 Undergraduate, 417 Master and 111 PhD.

[1] European Skills/Competences, Qualifications and Occupations: https://ec.europa.eu/esco/portal/escopedia/ESCO_version

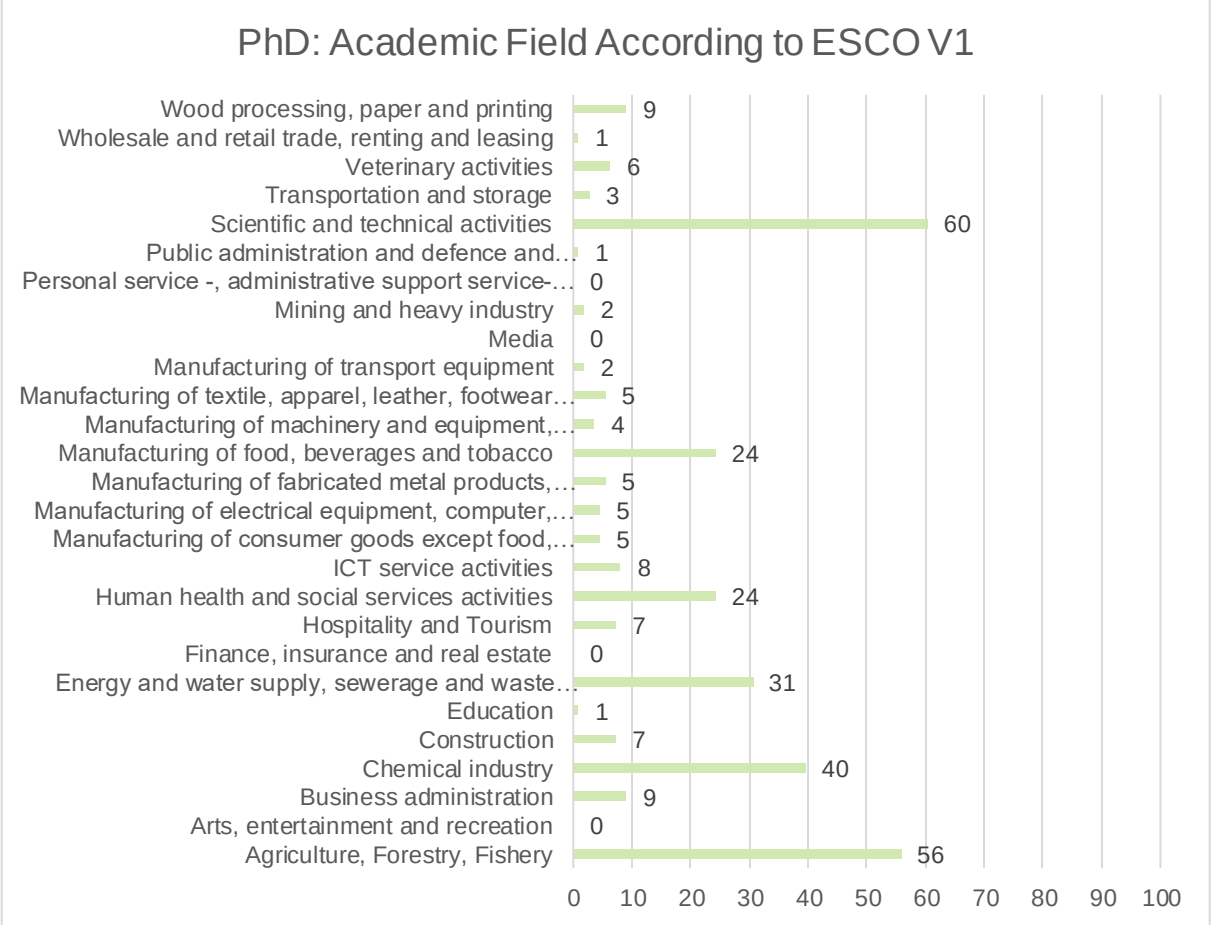


Figure 10: Academic fields of PhD programmes (in percentages).

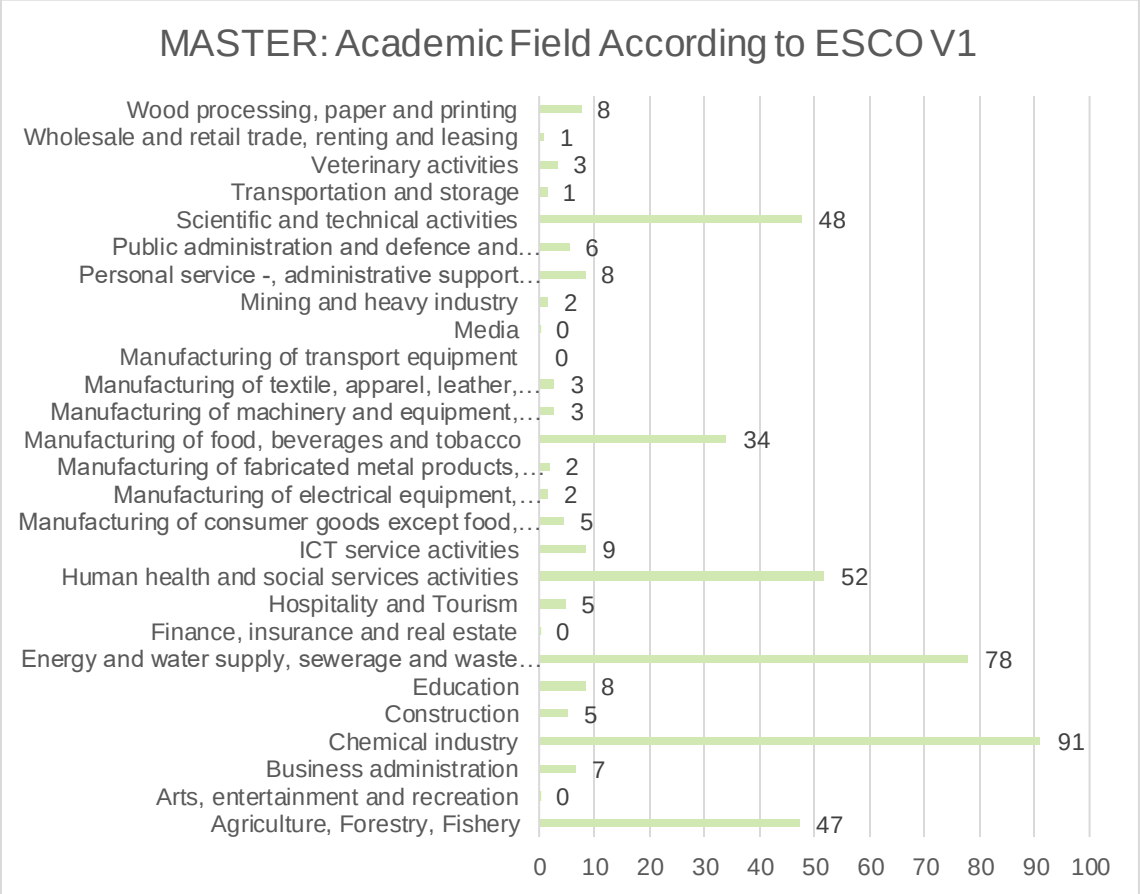


Figure 11: Academic fields of Master's programmes (in percentages).

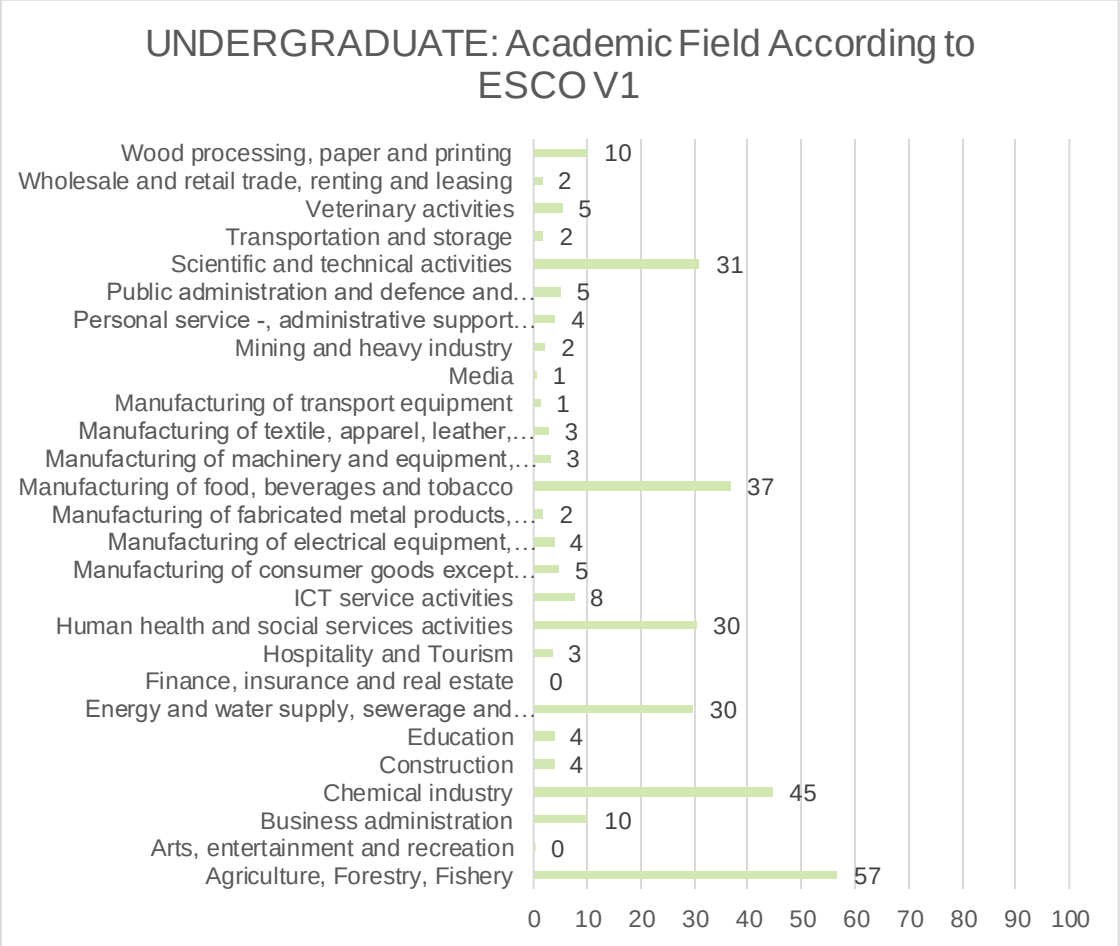


Figure 12: Academic fields of Undergraduate programmes (in percentages).

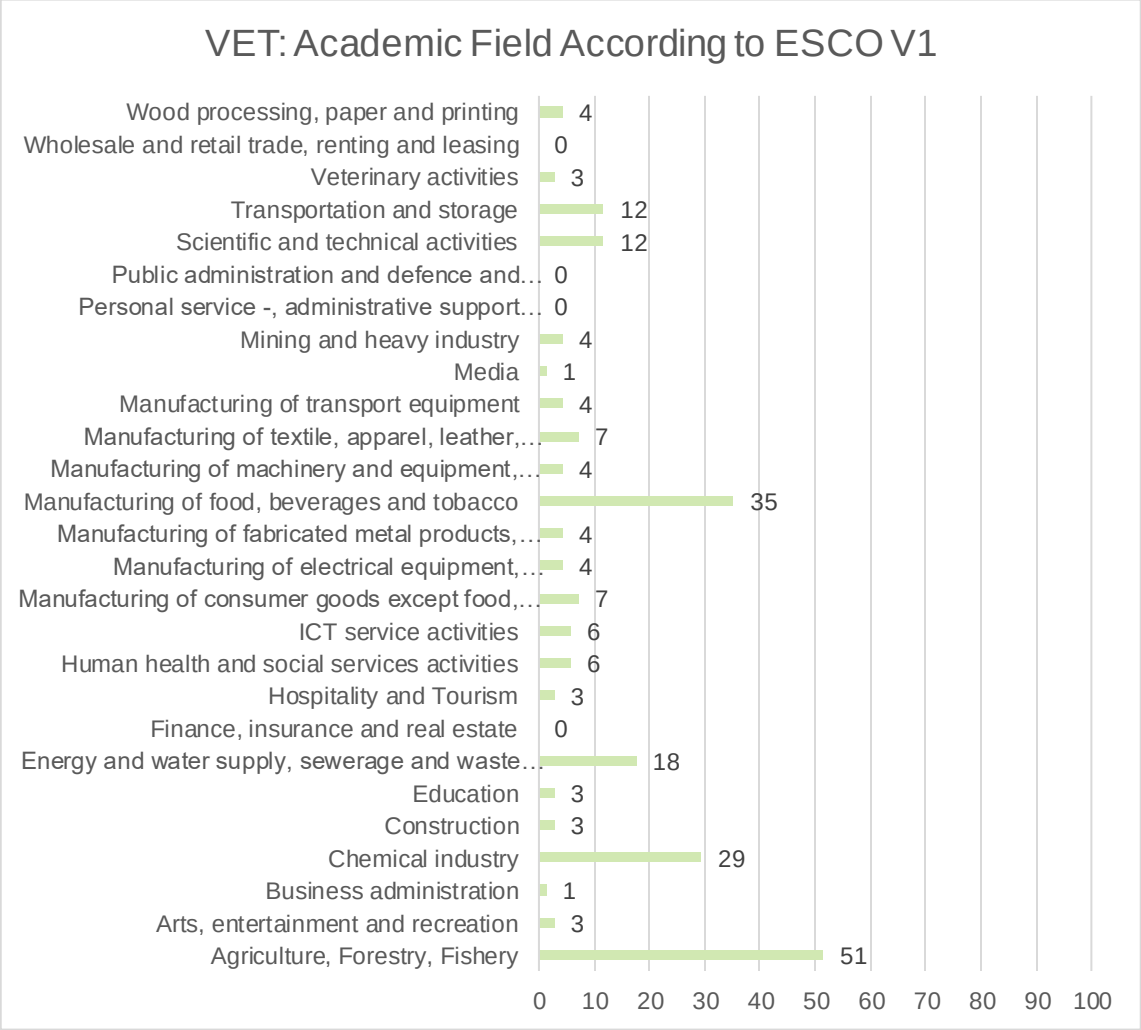


Figure 13: Academic fields of VET programmes (in percentages).

3.5 Bio-based Application Sectors

The most frequent application sectors identified in the descriptions of the different educational programmes are *Biotechnology*, *Agriculture* and *Food Products* across academic levels with the following distribution among the educational levels:

PhD: 1. - Biotechnology (55%) 2. - Agriculture (49%) 3. - Food Products (44%) 4. - Chemical (43%) 5. - Bioenergy (27%) 6. - Feed (26%)	**Master:** 1. - Biotechnology (56%) 2. - Food Products (51%) 3. - Agriculture (47%) 4. - Chemical (41%) 5. - Pharmaceuticals (32%) 6. - Bioenergy (30%)
Undergraduate: 1. - Agriculture (60%) 2. - Food Products (57%) 3. - Biotechnology (54%) 4. - Chemical (47%) 5. - Pharmaceuticals (34%) 6. - Beverages (34%)	**VET:** 1. - Agriculture (51%) 2. - Food Products (46%) 3. - Beverages (37%) 4. - Chemical (32%) 5. - Biotechnology (29%) 6. - Forestry (25%)

In the following figures (14-17) we can observe the distribution of the application sectors in percentages at the different educational levels analysed. The percentages on the following figures are calculated taking into account the total number of programmes analysed at each educational level: 68 VET, 316 Undergraduate, 417 Master and 111 PhD. Here we should also note that usually the same programme may apply to more than one industrial sector.

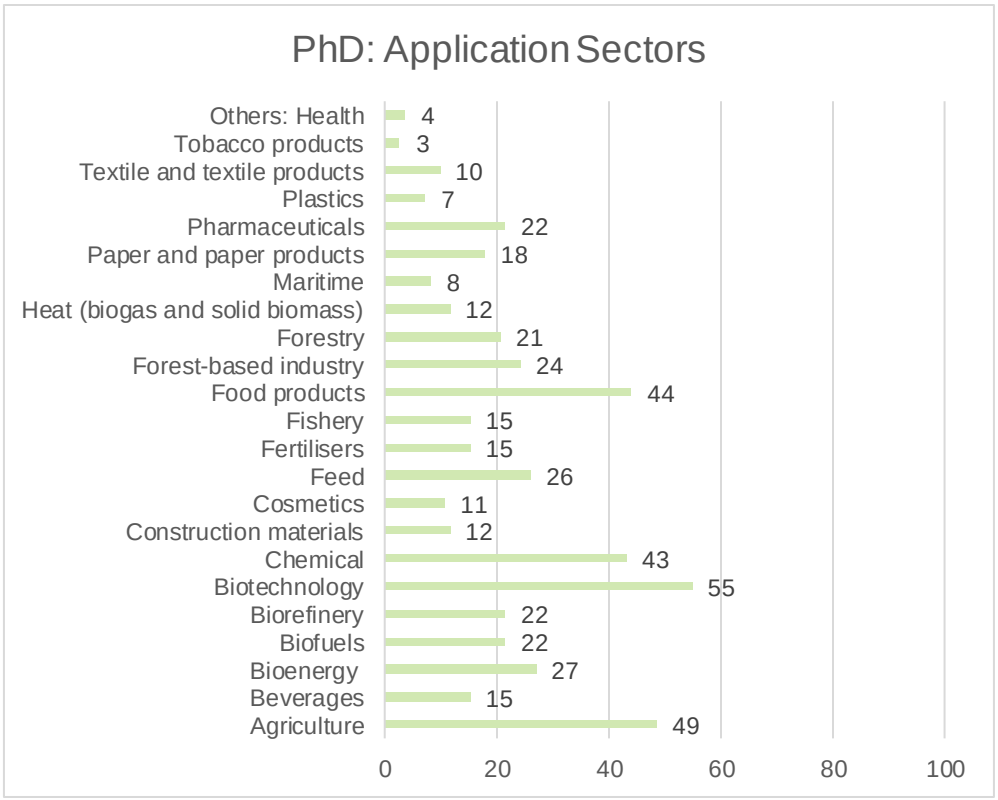


Figure 14: Industrial application sectors of PhD programmes (in percentages).

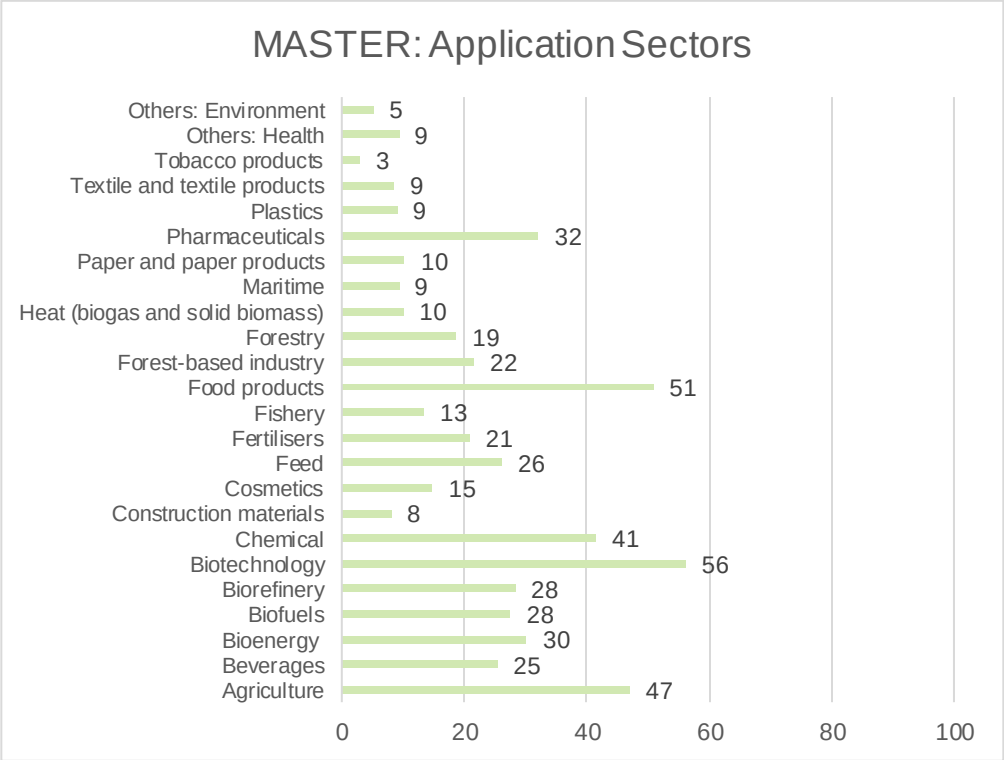


Figure 15: Industrial application sectors of Maser's programmes (in percentages).

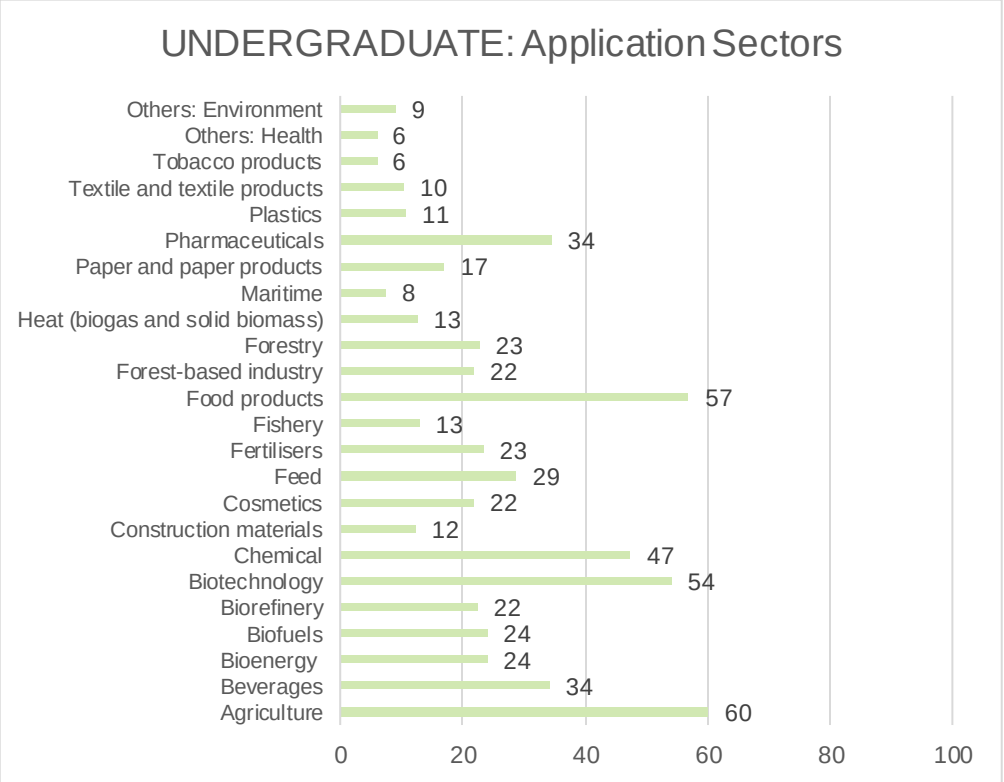


Figure 16: Industrial application sectors of Undergraduate programmes (in percentages).

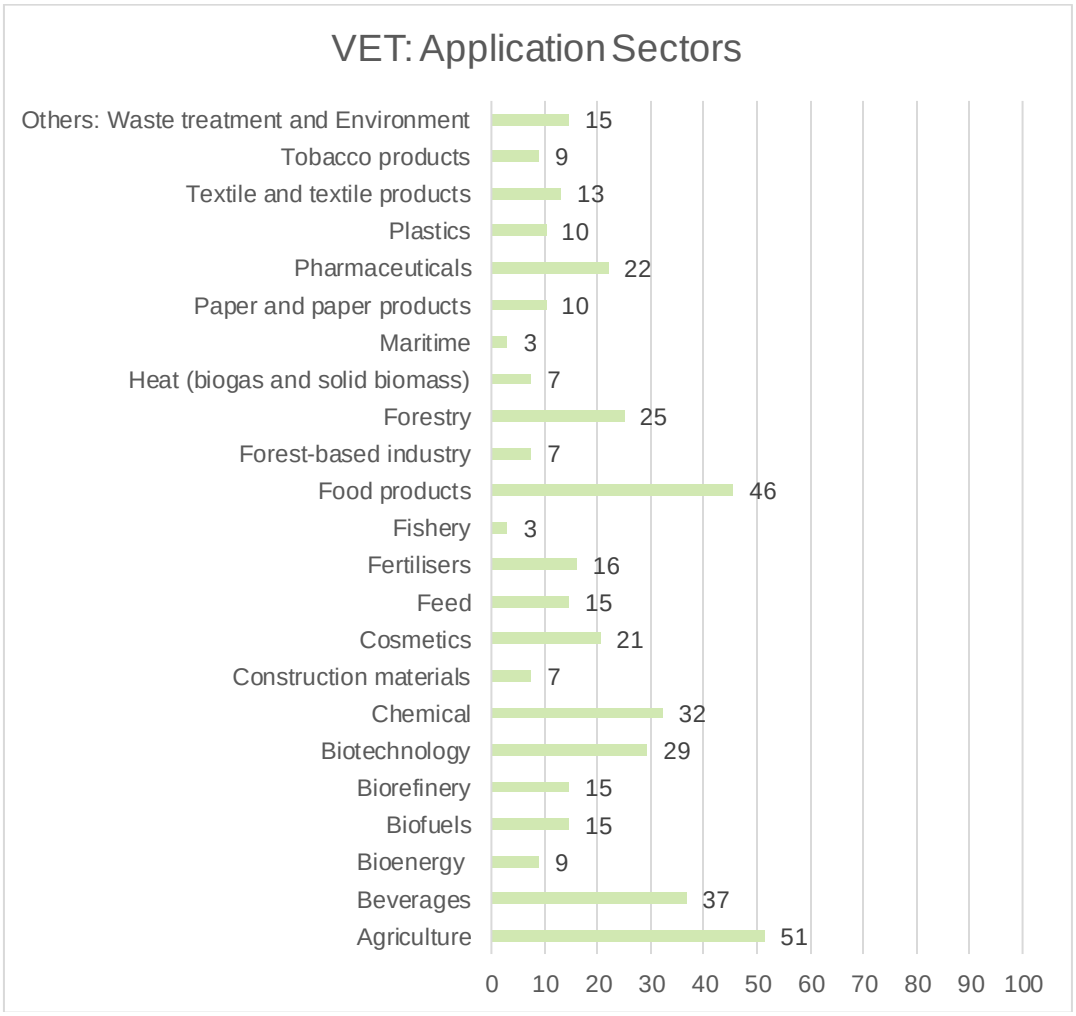


Figure 17: Industrial application sectors of VET programmes (in percentages)

3.6 General and Specific Competences for Bio-based industries

In order to understand the results in percentages of the study of general and specific competences and sub-competences, one should note that these percentages are calculated against the total number of possible answers in each case. This is a consequence of the structure and design of the EPT, where the lists of competences and sub-competences were optional, which means that informants where able to decide, according to the descriptions of the programmes available, whether to choose none, one or several competences or sub-competences from the list. The idea behind this design was to gather the frequency/intensity of presence of these items in the different programmes analysed. For this reason, the total percentage of the 11 general competences listed as well as the 5 specific competences listed are the sum of the percentages of sub-competences normalised by the total number of programmes analysed at each educational level: 111 PhD programmes, 417 Master's programmes, 316 Undergraduate programmes and 68 VET programmes. However, the percentages of the sub-competences are normalised according to the total number of actual answers for the general or specific competence where the particular sub-competence is classified at. The following chart shows the actual number of responses gathered at each competence:

COMPETENCES		TOTAL NUMBER OF RESPONSES			
	GENERAL COMPETENCES	**PhD**	**MASTER**	**UNDERGRAD.**	**VET**
1	Management	62	227	155	34
2	Data Management	48	116	87	9
3	Personal Initiative and entrepreneurship	61	211	147	32
4	Soft Skills	65	216	160	26
5	Sustainability and Industry	61	197	138	24
6	Technology	41	110	80	17
7	Research & Innovation	72	215	145	19
8	Basic Scientific Knowledge	67	256	228	49
9	Rules and Regulations	55	187	152	41
10	Social Responsibility - CSR	59	226	153	25
11	Sales and Marketing	39	106	74	14
	SPECIFIC COMPETENCES	**PhD**	**MASTER**	**UNDERGRAD.**	**VET**
1	Specialists in bio-based sector business/market development	32	109	55	9
2	Technical expertise in sustainable biomass production	47	110	68	16
3	Technical expertise in primary conversion processes	26	75	34	1
4	Technical expertise in secondary conversion processes	23	60	27	8
5	Technical expertise in materials, products and functionalisation	34	68	33	0

3.6.1 General Competences for Bio-based Industries

The general competences are represented at different degrees of intensity at each educational level and some patterns can also be observed in each general competence among all educational levels (see figure 18). The percentages on the following figures are calculated taking into account the total number of programmes analysed at each educational level: 68 VET, 316 Undergraduate, 417 Master and 111 PhD.

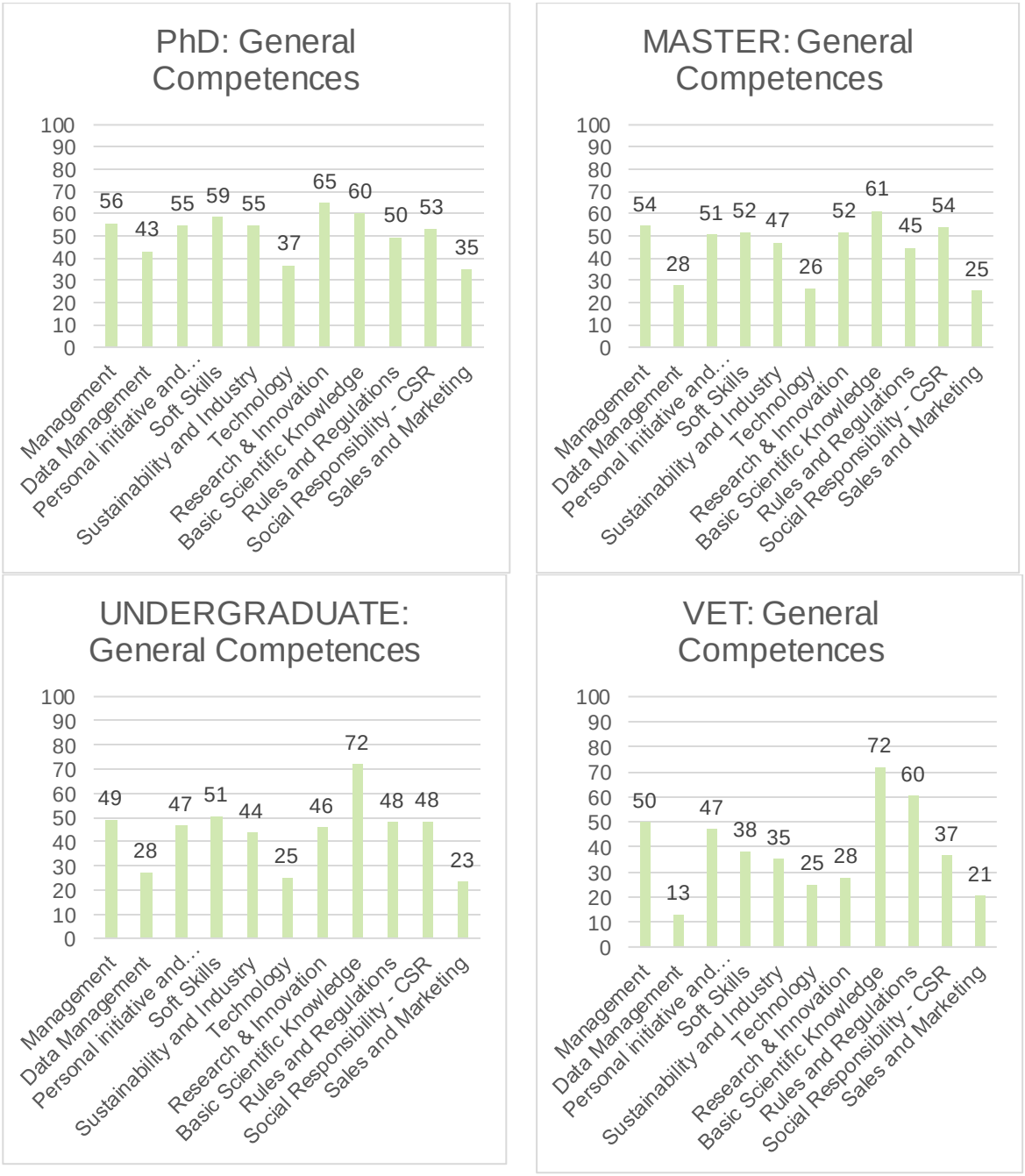


Figure 18: General competences identified at the four educational levels

Below each of the general competence categories is further analysed for their sub-competences for each educational level.

3.6.1.1 Management:

In the specific case of the *Management* sub-competences (see Figure 19), one might consider that *Purchasing* competence would be desirable and typical of the VET and Undergraduate levels.

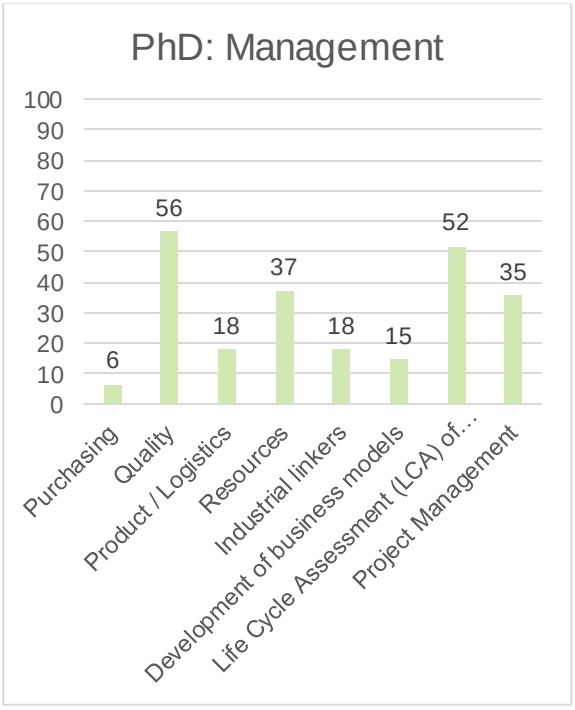
The sub-competences *Quality, Product / Logistics and Resources* are important at all levels, although with the general differences in approach as mentioned above between the different educational levels. The basic management skills would be important at VET and Undergraduate levels.

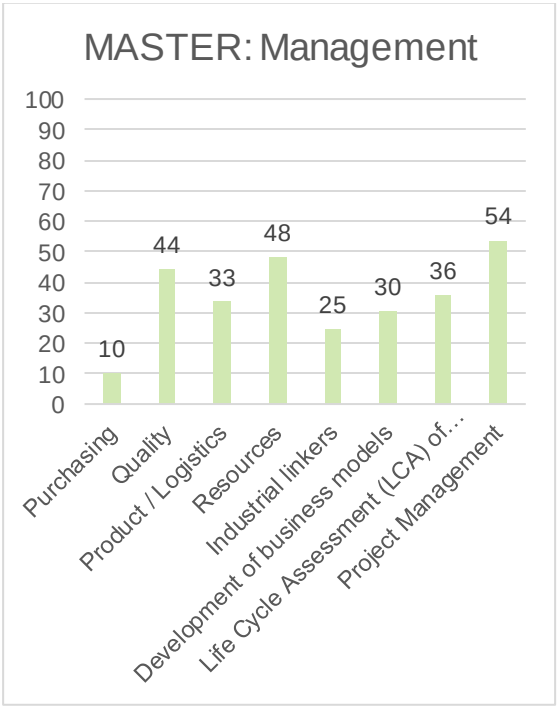
The *Industrial linkers* and *Development of business models* competences will be more typical of the Undergraduate and later stages.

The *Life Cycle Assessment* and *Project Management* competences would be present at all levels, although with the general differences in approach as mentioned above between the different educational levels. The basic skills would be important in the stages of VET and Undergraduate. The *Life Cycle Assessment* competence would gain more importance in Undergraduate and PhD whereas *Project Management* is more relevant in Undergraduate and Master.

The following figure represents the distribution of sub-competences in percentages normalised by the number of actual responses for this competence at each educational level:

- 62 PhD programmes out of 111 total PhD programmes analysed address this competence.
- 227 Master's programmes out of 417 total Master's programmes analysed address this competence.
- 155 Undergraduate programmes out of 316 total Undergraduate programmes analysed address this competence.
- 34 VET programmes out of 68 total VET programmes analysed address this competence.





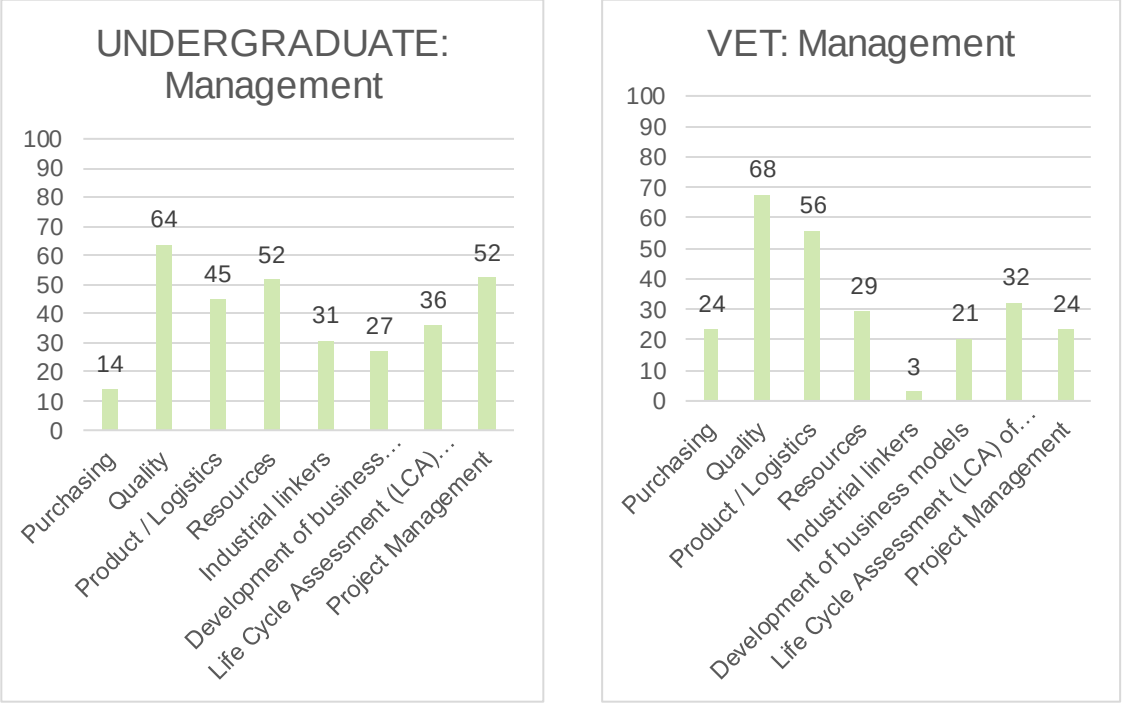


Figure 19: Management sub-competences at the four educational levels.

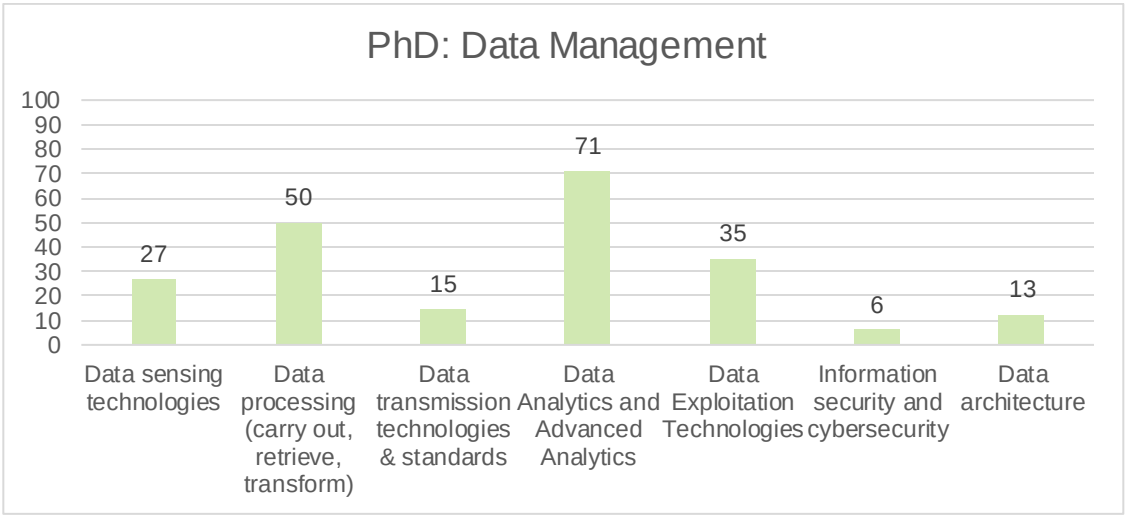
3.6.1.2. Data Management:

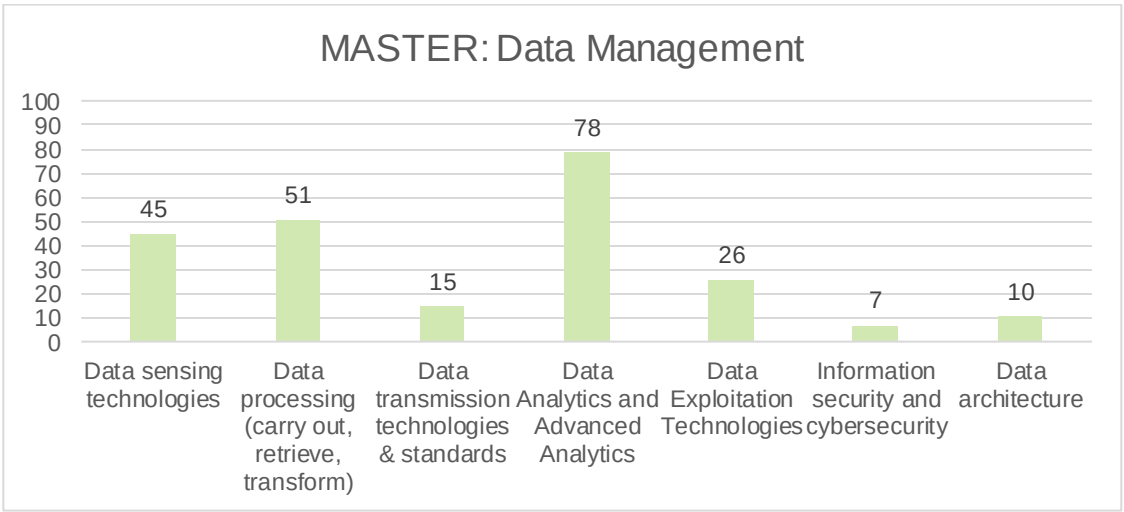
Figure 20 refers to the contributions focused on the *Data Management* competence and, in this regard, and considering the commented levels of complexity that can be established between the different studies, it should be noted that:

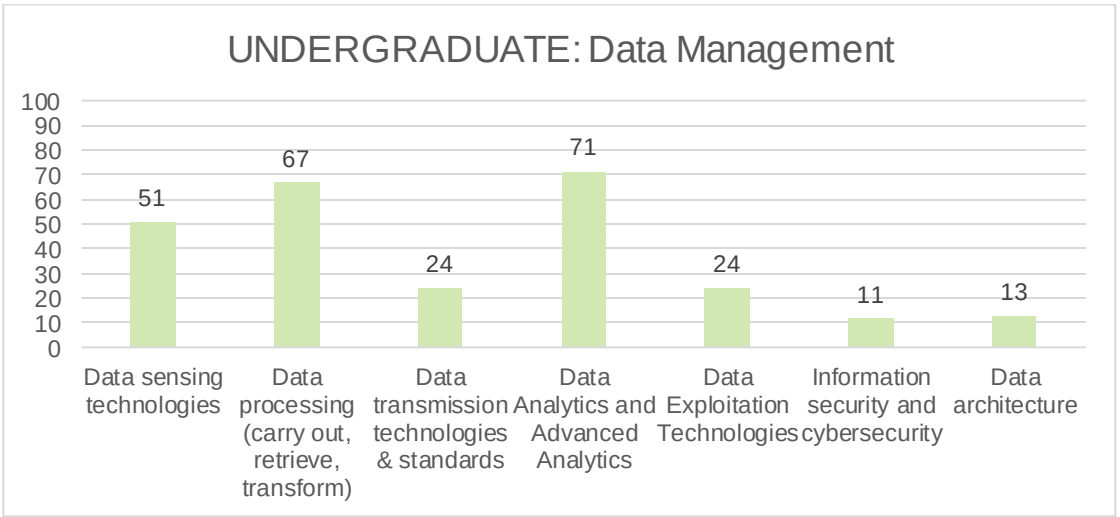
- The sub-competences of *Data sensing Technologies, Data processing and Information security and cybersecurity* are more frequently identified within the VET and Undergraduate studies, with the possibility of deepening aspects of innovation and research in higher studies.
- The *Data Analytics, Advanced Analytics and Data architecture* sub-competences must work at all educational levels.
- The sub-competence of *Data transmission technologies & standards* would be more characteristic of the Undergraduate level, while the one linked to *Data exploitation Technologies* should be deepened in the Masters and PhDs programmes.

The following figure represents the distribution of sub-competences in percentages normalised by the number of actual responses for this competence at each educational level:

- 48 PhD programmes out of 111 total PhD programmes analysed address this competence.
- 116 Master's programmes out of 417 total Master's programmes analysed address this competence.
- 87 Undergraduate programmes out of 316 total Undergraduate programmes analysed address this competence.
- 9 VET programmes out of 68 total VET programmes analysed address this competence.


PhD: Data Management
100
90
80
70
60
50
40
30
20
10
0
27
50
15
71
35
6
13
Data sensing technologies
Data processing (carry out, retrieve, transform)
Data transmission technologies & standards
Data Analytics and Advanced Analytics
Data Exploitation Technologies
Information security and cybersecurity
Data architecture


MASTER: Data Management
100
90
80
70
60
50
40
30
20
10
0
45
51
15
78
26
7
10
Data sensing technologies
Data processing (carry out, retrieve, transform)
Data transmission technologies & standards
Data Analytics and Advanced Analytics
Data Exploitation Technologies
Information security and cybersecurity
Data architecture


UNDERGRADUATE: Data Management
100
90
80
70
60
50
40
30
20
10
0
51
67
24
71
24
11
13
Data sensing technologies
Data processing (carry out, retrieve, transform)
Data transmission technologies & standards
Data Analytics and Advanced Analytics
Data Exploitation Technologies
Information security and cybersecurity
Data architecture

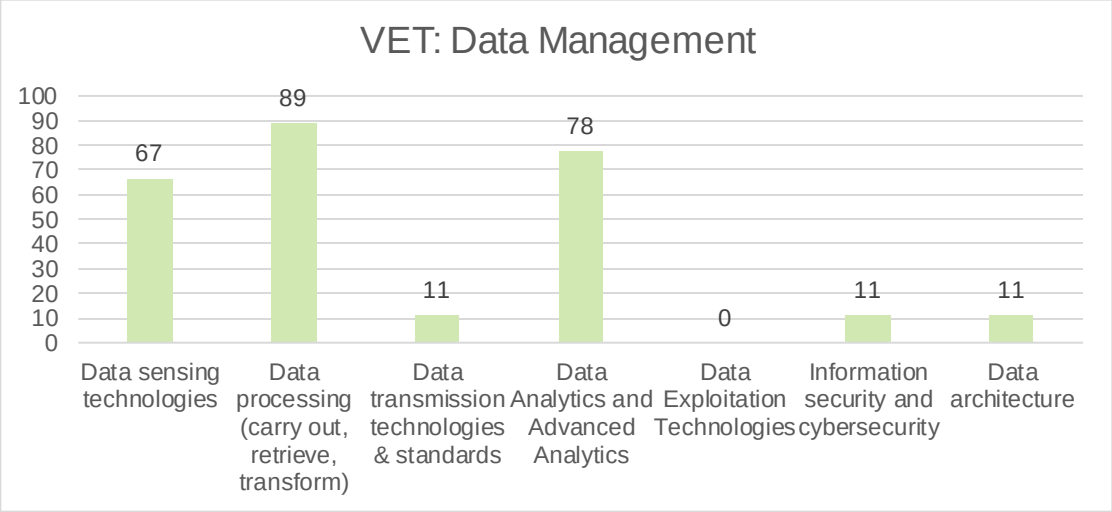


Figure 20: Data Management sub-competences at the four educational levels.

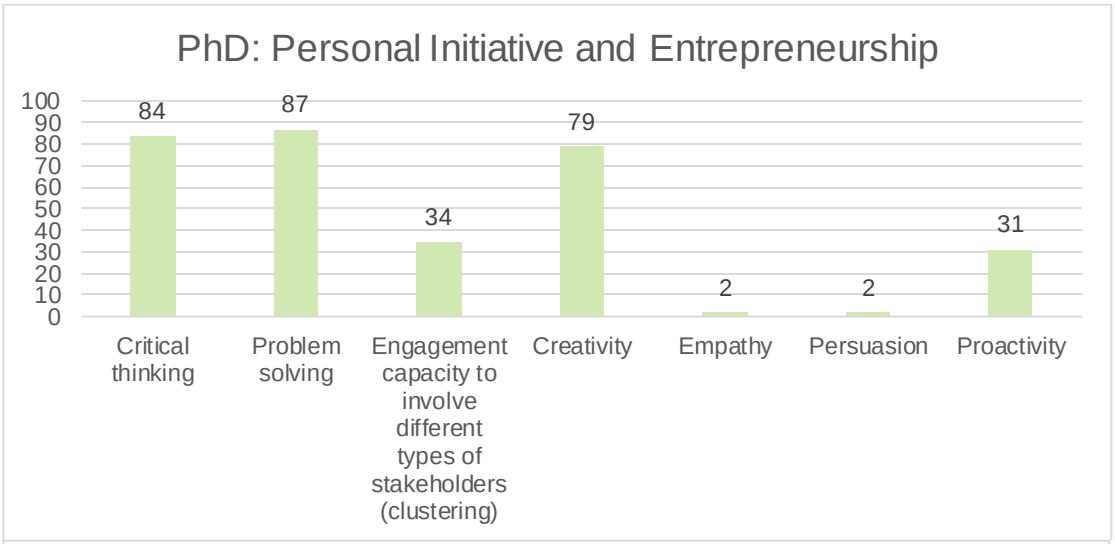
3.6.1.3. Personal Initiative and Entrepreneurship

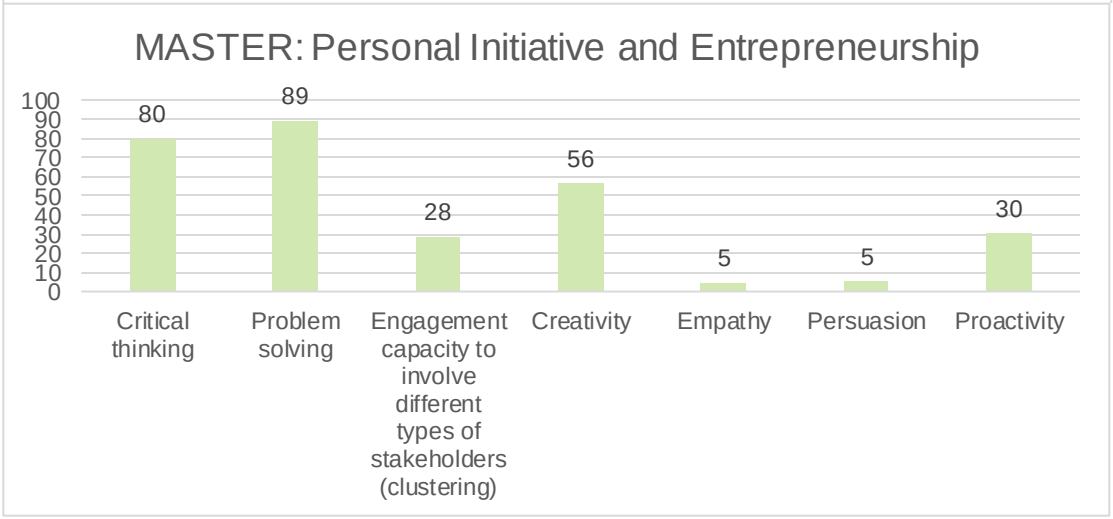
Figure 21 refers to the contributions focused on the *Personal Initiative and Entrepreneurship competence*, and, in this regard and considering the commented levels of complexity that can be established between the different studies, it should be noted that:

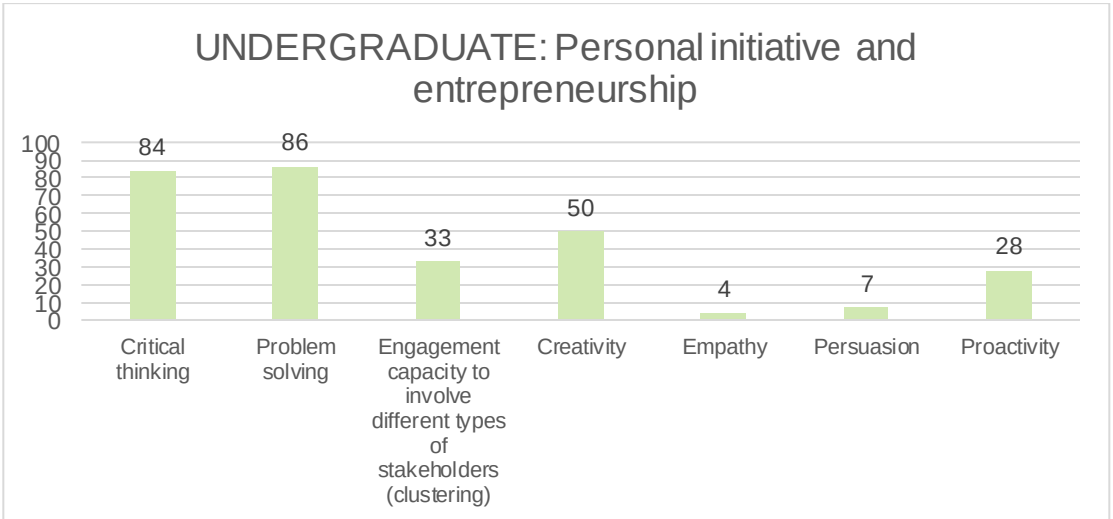
- The skills of *Critical thinking, Problem Solving and Creativity* are considered at all the educational levels, taking into account that it is more highly valued at PhD level.
- The sub-competence of *Engagement capacity to involve different types of stakeholders* is also evident at all training cycles, although with greater emphasis on VET. The same goes for the *Proactivity* sub-competence.
- The skills of *Empathy and Persuasion* are practically not considered at any of the established educational levels.

The following figure represents the distribution of sub-competences in percentages normalised by the number of actual responses for this competence at each educational level:

- 61 PhD programmes out of 111 total PhD programmes analysed address this competence.
- 211 Master's programmes out of 417 total Master's programmes analysed address this competence.
- 147 Undergraduate programmes out of 316 total Undergraduate programmes analysed address this competence.
- 32 VET programmes out of 68 total VET programmes analysed address this competence.


PhD: Personal Initiative and Entrepreneurship
100
90
80
70
60
50
40
30
20
10
0
84
87
34
79
2
2
31
Critical thinking
Problem solving
Engagement capacity to involve different types of stakeholders (clustering)
Creativity
Empathy
Persuasion
Proactivity


MASTER: Personal Initiative and Entrepreneurship
100
90
80
70
60
50
40
30
20
10
0
80
89
28
56
5
5
30
Critical thinking
Problem solving
Engagement capacity to involve different types of stakeholders (clustering)
Creativity
Empathy
Persuasion
Proactivity


UNDERGRADUATE: Personal initiative and entrepreneurship
100
90
80
70
60
50
40
30
20
10
0
84
86
33
50
4
7
28
Critical thinking
Problem solving
Engagement capacity to involve different types of stakeholders (clustering)
Creativity
Empathy
Persuasion
Proactivity

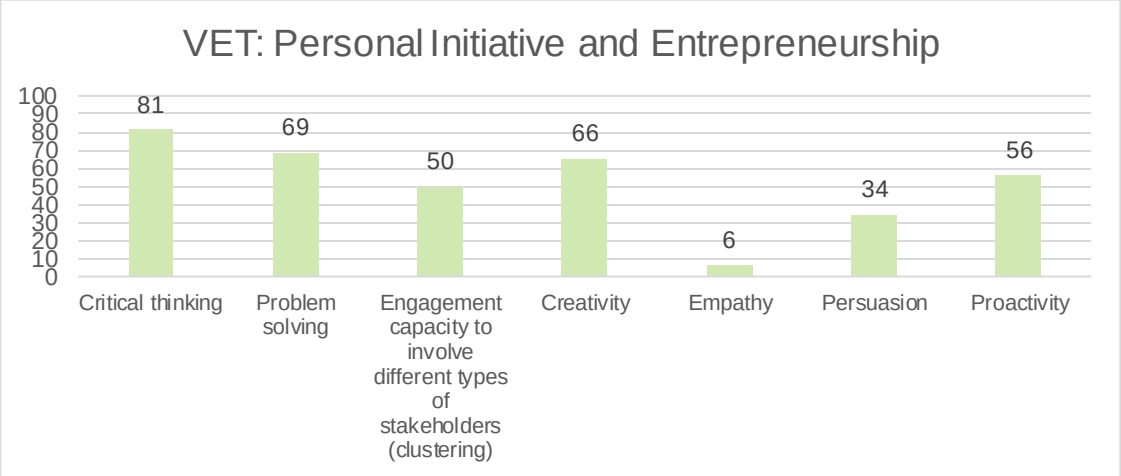


Figure 21: Personal Initiative and Entrepreneurship sub-competences at the four educational levels.

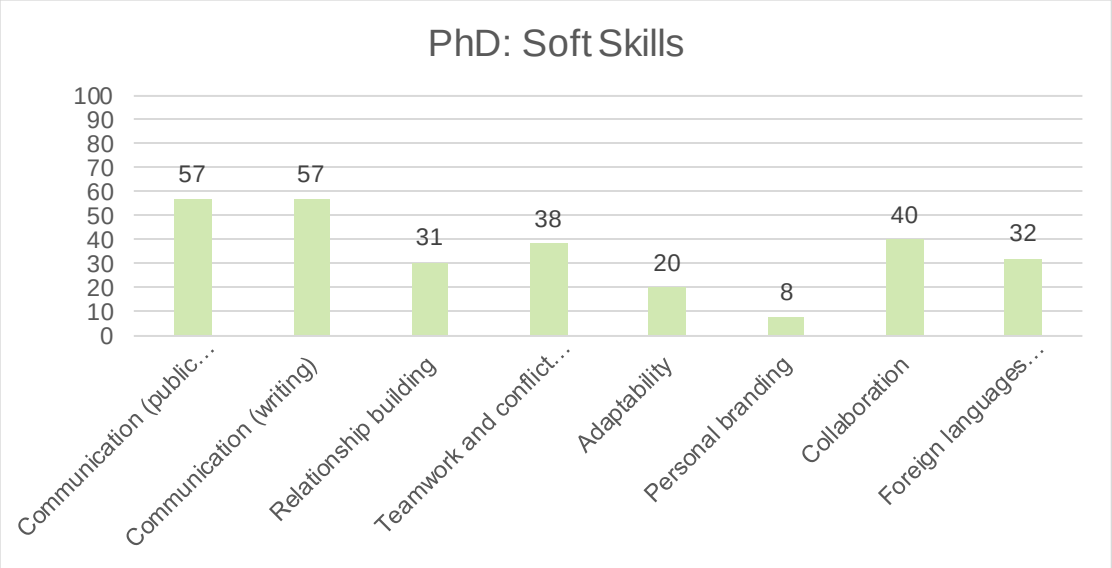
3.6.1.4. Soft Skills:

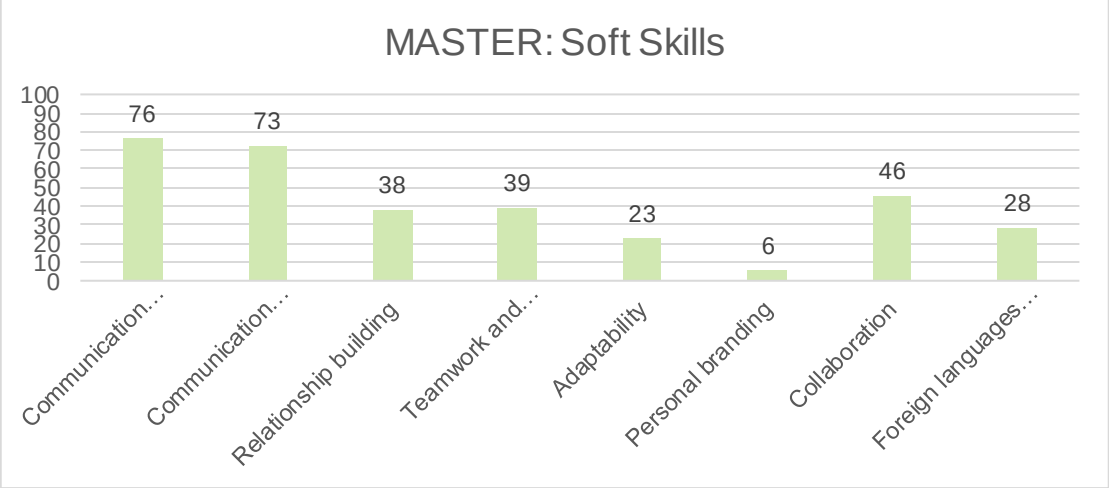
Figure 22 refers to the contributions focused on *Soft Skills* and, in this regard and considering the commented levels of complexity that can be established between the different studies, it should be noted that:

- The skills of *Communication (public speaking)* and *Communication (writing)* are considered important at all educational levels; however, they must be subject to a higher level of mastery at the Undergraduate and Master levels.
- *Relationship and Collaboration* competences appear in similar percentages in the different degrees and are also considered necessary. The *Foreign languages* competence is especially present and similarly in the Undergraduate, Master and PhD studies.
- *Teamwork and conflict resolution* competence is present in all studies, although to a greater extent in Undergraduate and PhD; while *Adaptability and Personal branding* is much more relevant at VET.

The following figure represents the distribution of sub-competences in percentages normalised by the number of actual responses for this competence at each educational level:

- 65 PhD programmes out of 111 total PhD programmes analysed address this competence.
- 216 Master's programmes out of 417 total Master's programmes analysed address this competence.
- 160 Undergraduate programmes out of 316 total Undergraduate programmes analysed address this competence.
- 26 VET programmes out of 68 total VET programmes analysed address this competence.


PhD: Soft Skills
100
90
80
70
60
50
40
30
20
10
0
57
57
31
38
20
8
40
32
Communication (public…
Communication (writing)
Relationship building
Teamwork and conflict…
Adaptability
Personal branding
Collaboration
Foreign languages…


MASTER: Soft Skills
100
90
80
70
60
50
40
30
20
10
0
76
73
38
39
23
6
46
28
Communication…
Communication…
Relationship building
Teamwork and…
Adaptability
Personal branding
Collaboration
Foreign languages…

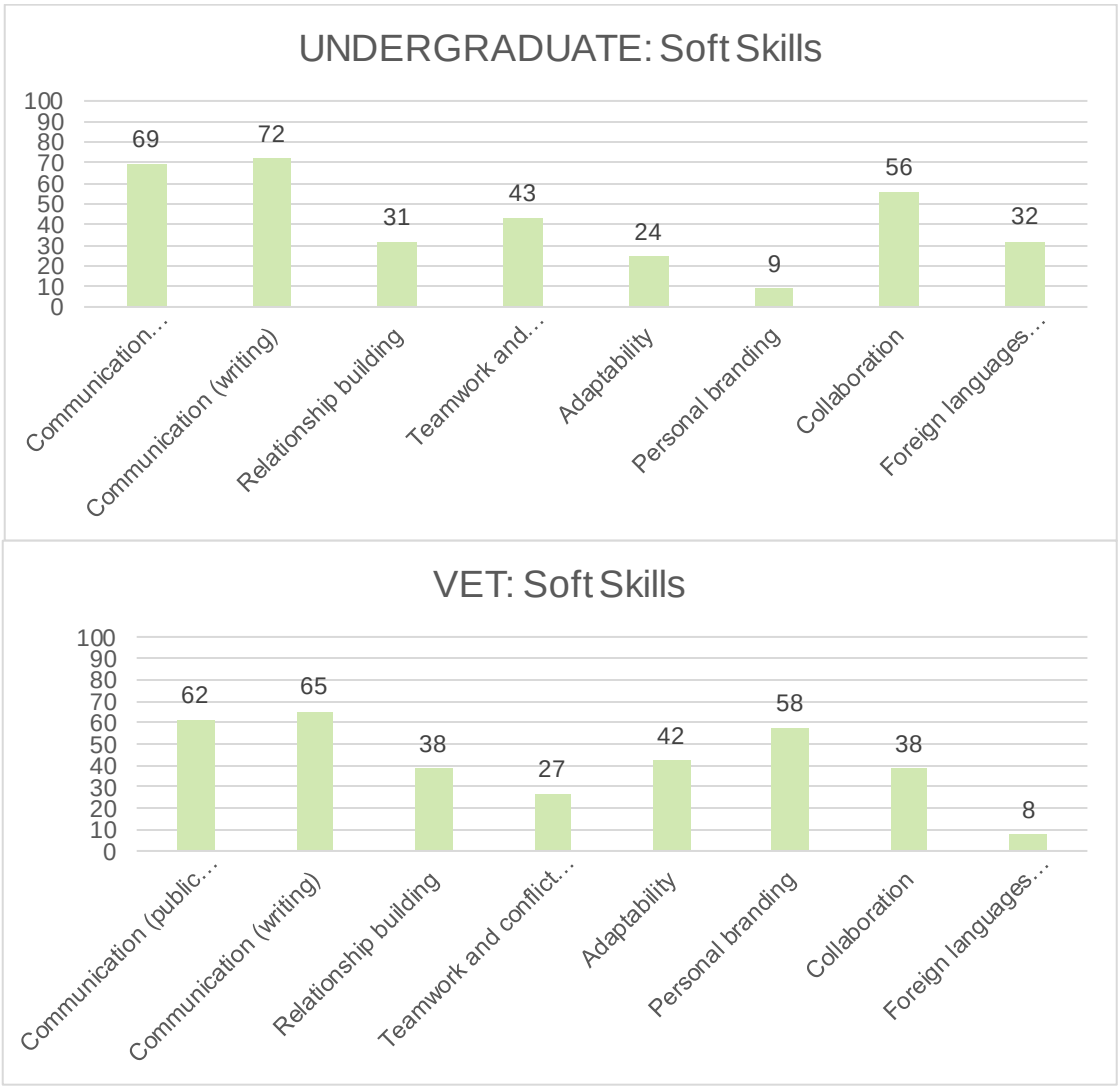


Figure 22: Soft Skills sub-competences at the four educational levels.

3.6.1.5. Sustainability and Industry:

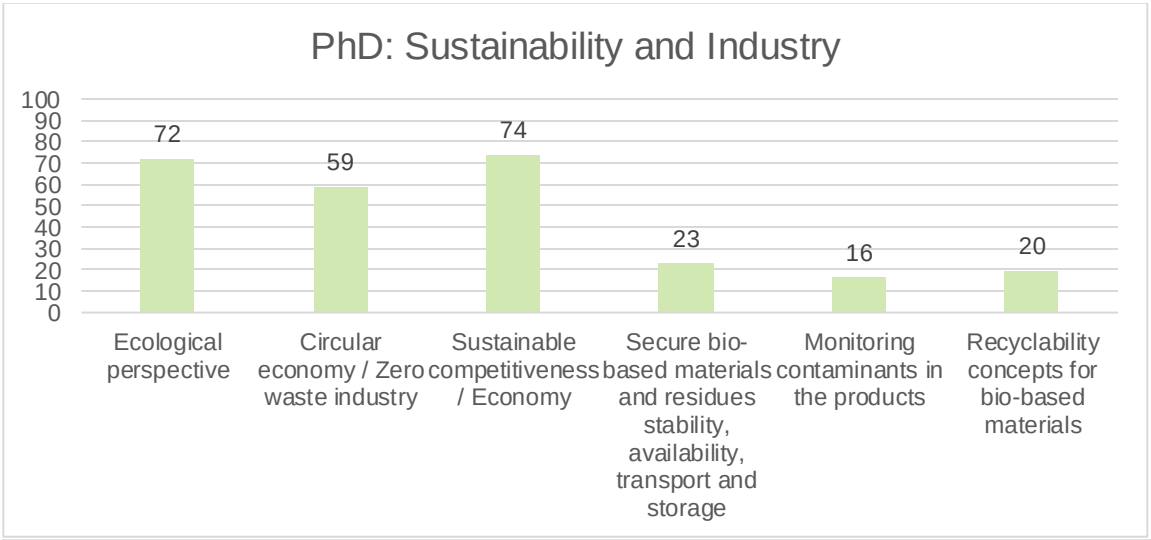
In Figure 23 we can see the behaviour of the responses related to the *Sustainability and Industry* competence, which are specified in 6 subcategories. Results are significantly different from each other, which implies that the informants have differentiated between the different components of this competence. More specifically, it could be noted that:

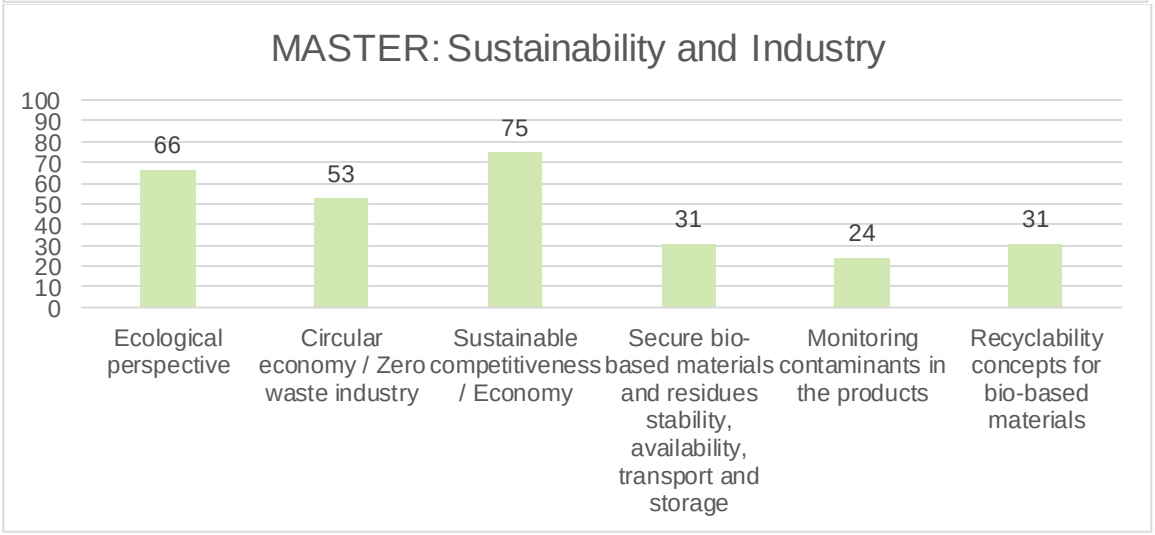
- Regarding the *Ecological perspective* sub-competence perspective shows the most outstanding difference among the different educational levels. Mastering this competence seems to be more important at PhD than at VET, with a difference of 14 percentage points.
- Contrary to the previous trend, sub-competence on the *Monitoring contaminants in products* also provides a significant difference between the VET level, 33%, and PhD level, 16%; 17 points difference that allows us to draw a pattern where monitoring is attributed to a more technical profile and not so much for a PhD researcher, probably because it has to do with a control over functions.

- The most remarkable difference with more than 30 points difference is in the *Circular economy* category, where it is considered more relevant at Master's and PhD higher levels and not so much for the VET educational level.

The following figure represents the distribution of sub-competences in percentages normalised by the number of actual responses for this competence at each educational level:

- 61 PhD programmes out of 111 total PhD programmes analysed address this competence.
- 197 Master's programmes out of 417 total Master's programmes analysed address this competence.
- 138 Undergraduate programmes out of 316 total Undergraduate programmes analysed address this competence.
- 24 VET programmes out of 68 total VET programmes analysed address this competence.





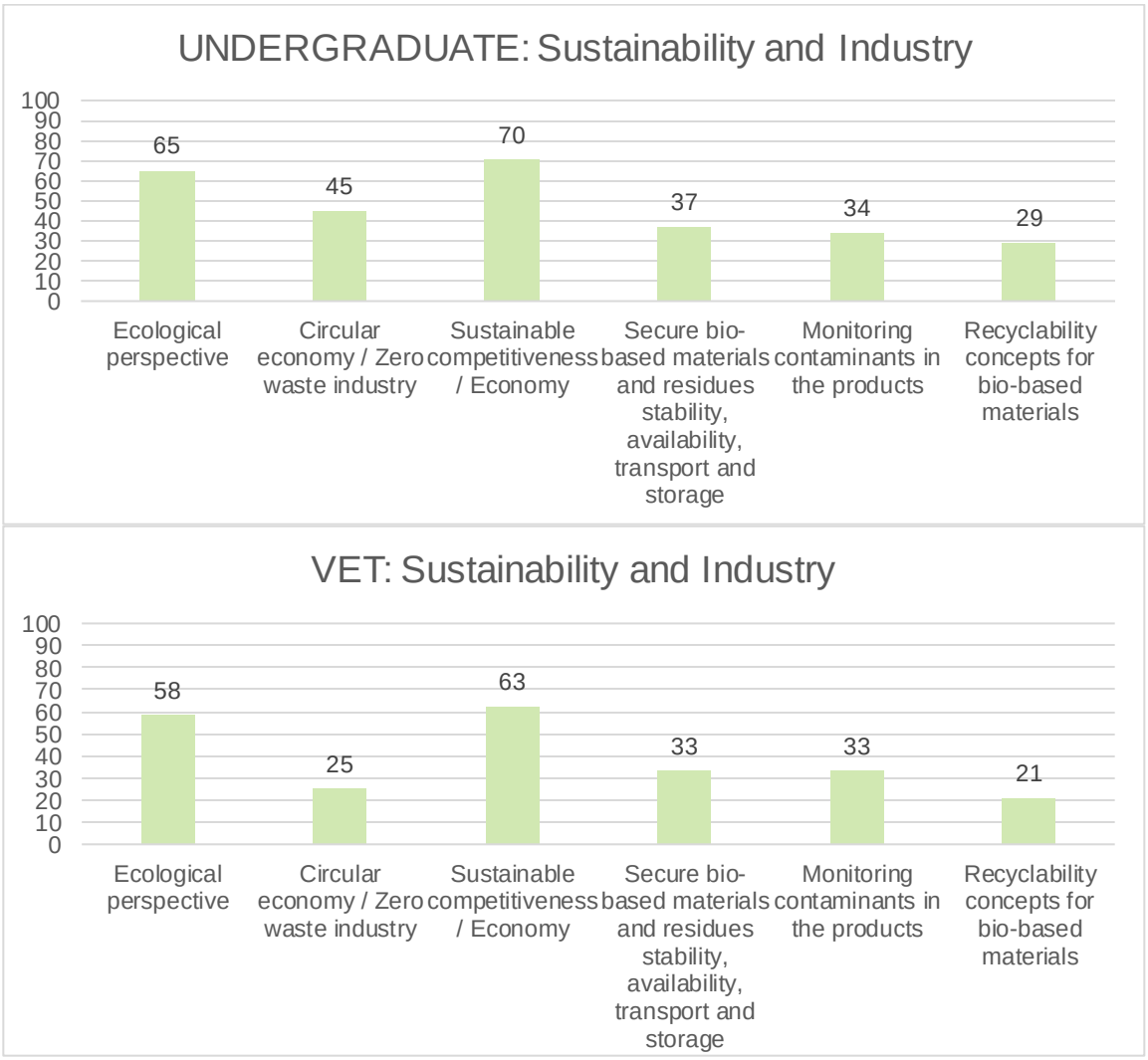


Figure 23: Sustainability and Industry sub-competences at the four educational levels.

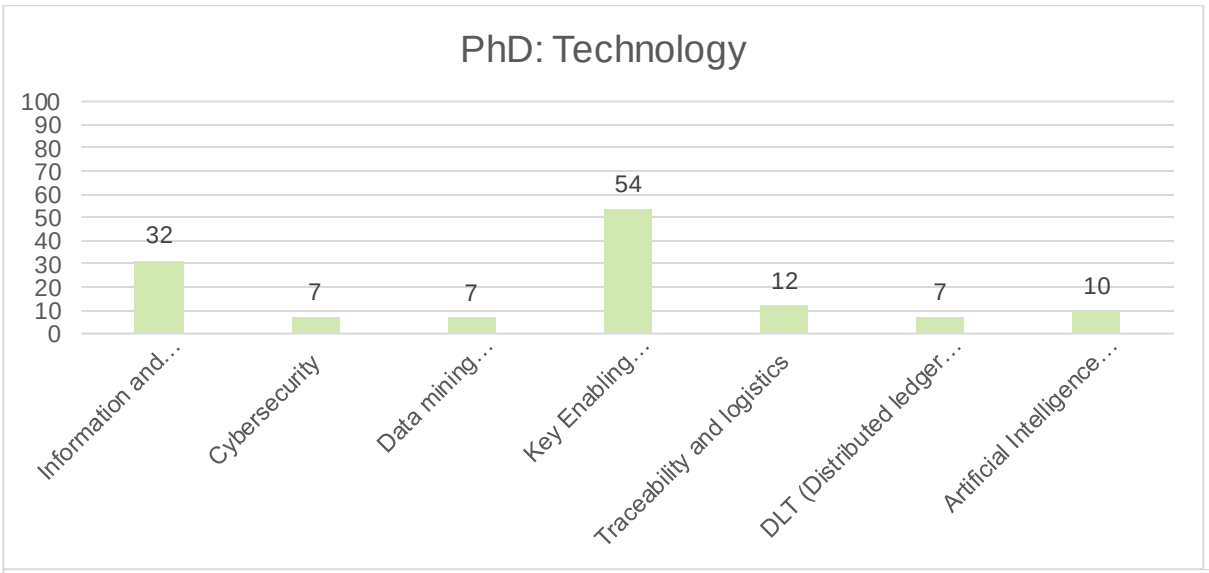
3.6.1.6 Technology:

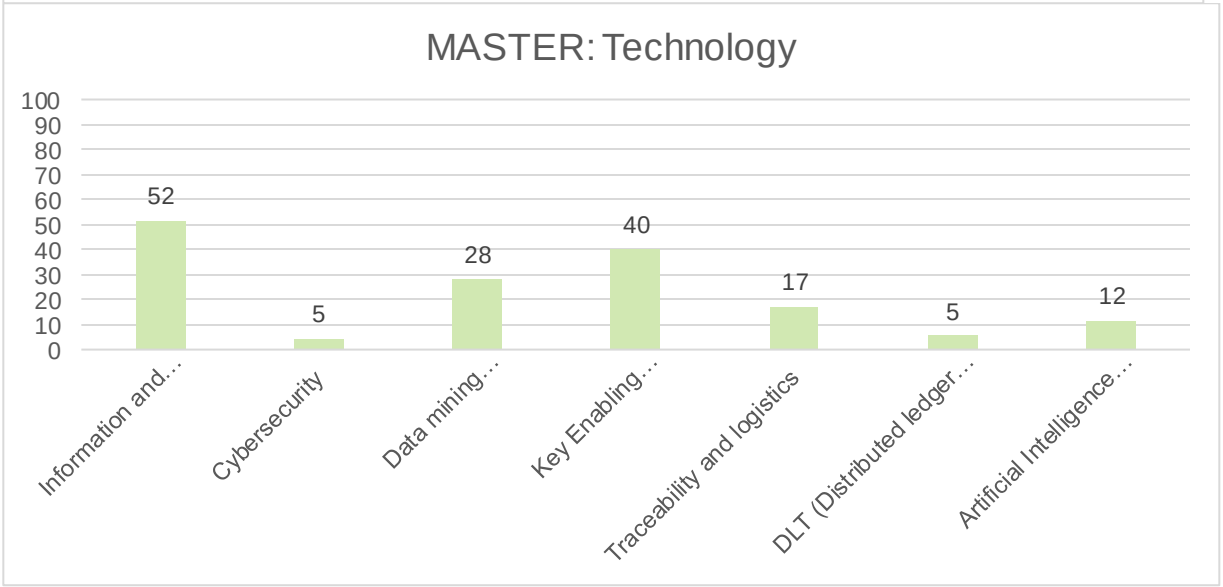
Figure 24 shows the answers regarding the *Technology* competence and sub-competences at the four educational levels. For this competence the differences between all the associated components are very significant and also the differences between the educational levels required for each of its categories.

- *Traceability and logistics* is considered to be leveraged specifically for each educational level being almost unnecessary to be developed at PhD level (12%) but very necessary in the development of functions for VET level students (79%).
- Likewise, the informants consider that for the level of development of VET training, out of the 7 subcategories, 3 should not be within the scope of this competence: *data mining tools / strategies, key enabling technologies for the bio based industry and DLT*.
- We conclude with another significant differentiation between levels in relation to the subcategory *Key enabling technologies for the bio-based industry*, because as mentioned before, it does not require any implementation at VET level, whereas it is ranked at 34% for Undergraduate, 40% for Master and 54% for PhD level.

The following figure represents the distribution of sub-competences in percentages normalised by the number of actual responses for this competence at each educational level:

- 41 PhD programmes out of 111 total PhD programmes analysed address this competence.
- 110 Master's programmes out of 417 total Master's programmes analysed address this competence.
- 80 Undergraduate programmes out of 316 total Undergraduate programmes analysed address this competence.
- 17 VET programmes out of 68 total VET programmes analysed address this competence.





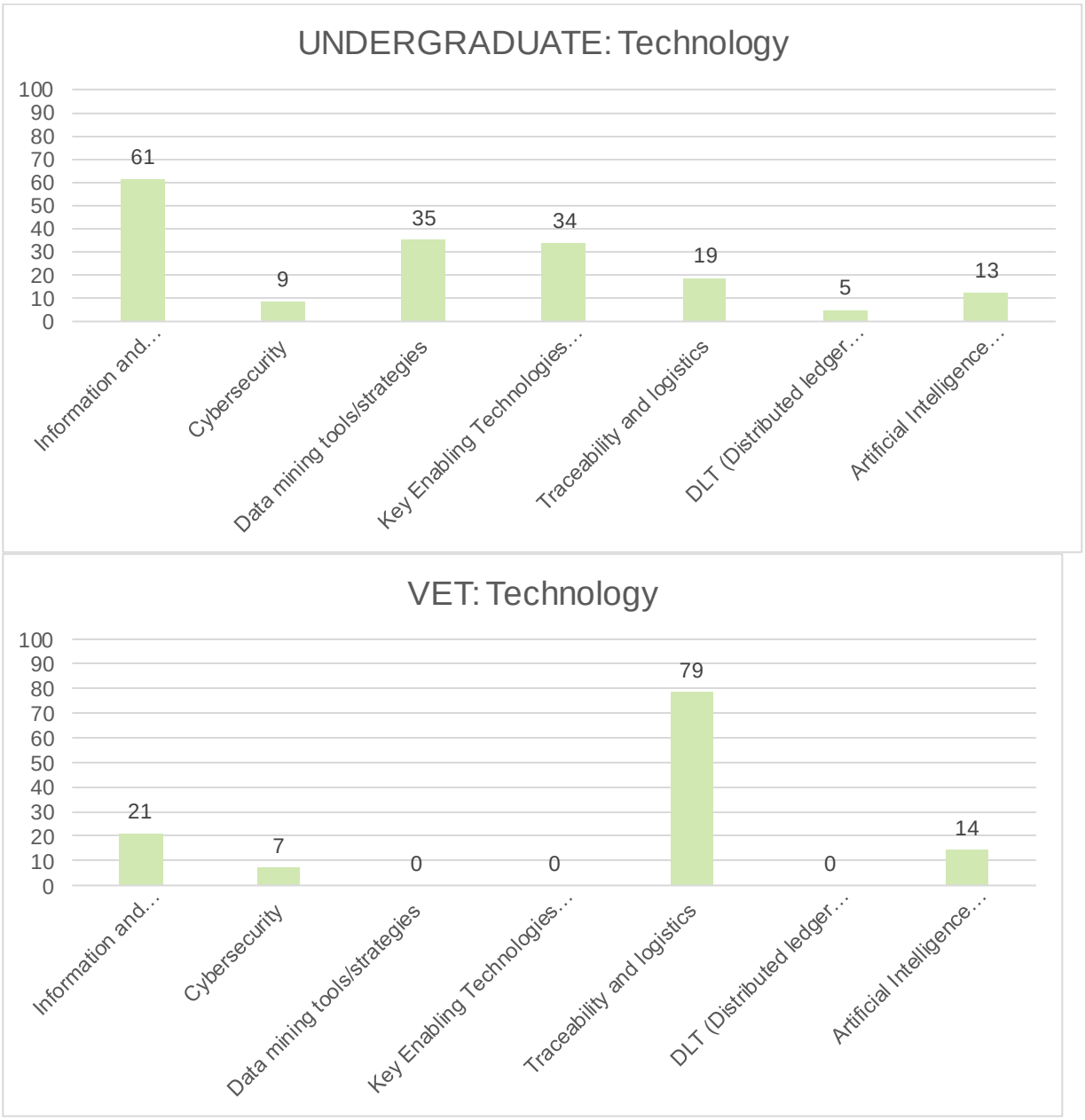


Figure 24: Technology sub-competences at the four educational levels.

3.6.1.7. Research and Innovation:

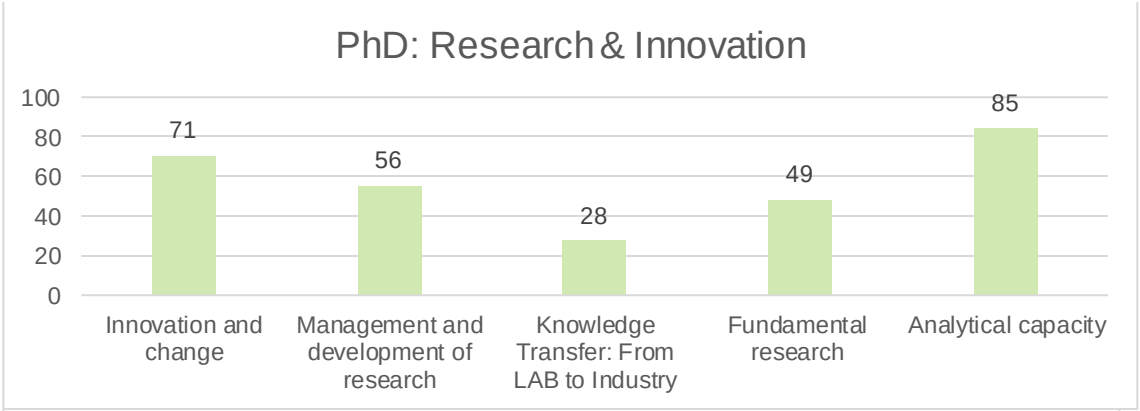
The different responses regarding the *Research and Innovation* competence and sub-competences at the four educational levels are shown in Figure 25. The results in this case, although expected, are very significant and relevant. One of the basic and inherent functions of PhD researchers and staff is linked to research and innovation.

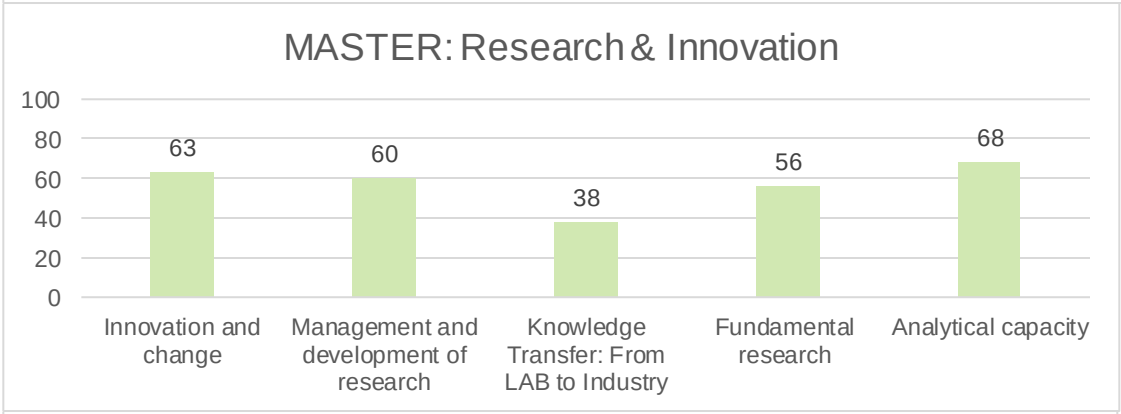
- *Research and innovation* subcategories for PhD are highly valued in all fields, highlighting the ability to analyse, although this dimension is also required by all other levels, even for VET.
- The *Innovation and Change* capacity is essential for PhDs and Masters' and is significantly reduced at other educational levels, being moderate at the VET level.

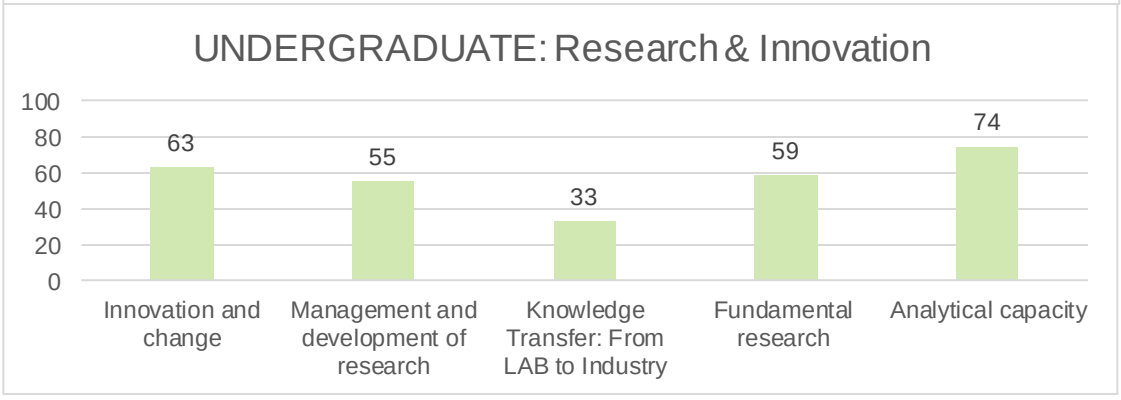
- Research sub-competences for VET in *Management and development of research* or *Fundamental research* are not considered.

The following figure represents the distribution of sub-competences in percentages normalised by the number of actual responses for this competence at each educational level:

- 72 PhD programmes out of 111 total PhD programmes analysed address this competence.
- 215 Master's programmes out of 417 total Master's programmes analysed address this competence.
- 145 Undergraduate programmes out of 316 total Undergraduate programmes analysed address this competence.
- 19 VET programmes out of 68 total VET programmes analysed address this competence.







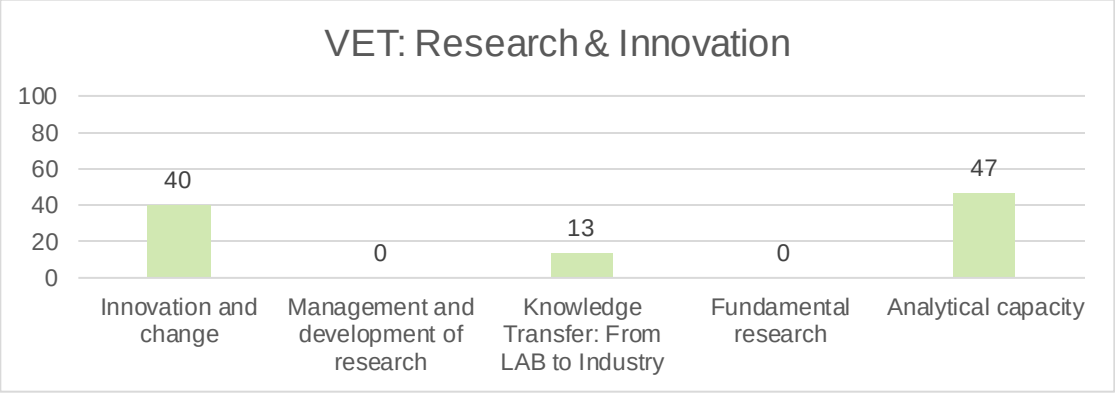


Figure 25: Research and Innovation sub-competences at the four educational levels.

3.6.1.8. Basic Scientific Knowledge:

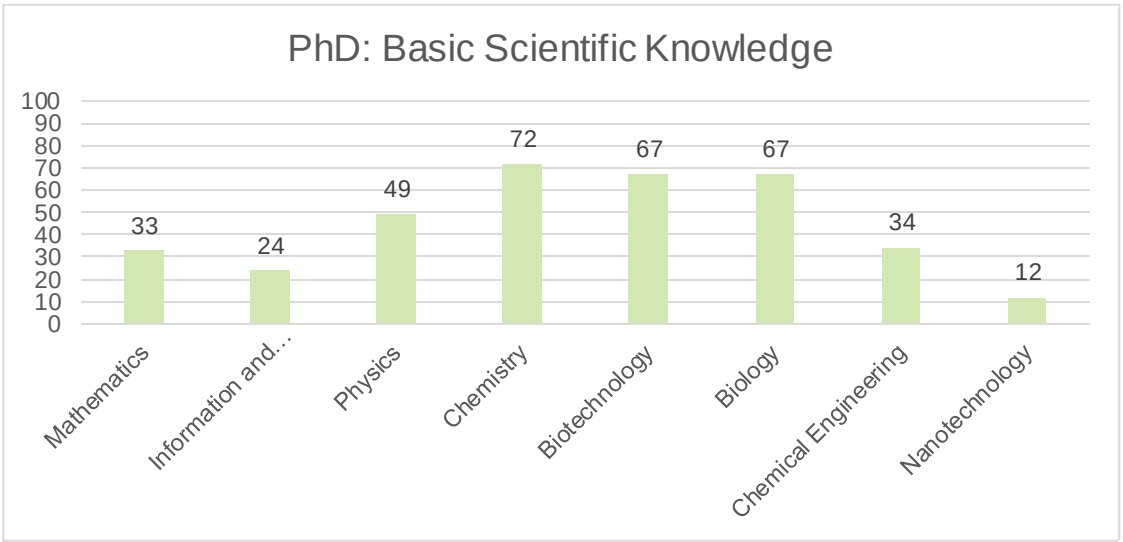
Regarding *Basic Scientific Knowledge* competence and as Figure 26 shows, all sub-competences are present at the different educational levels with the exception of *Nanotechnology*, which is not identified as a sub-competence for VET level.

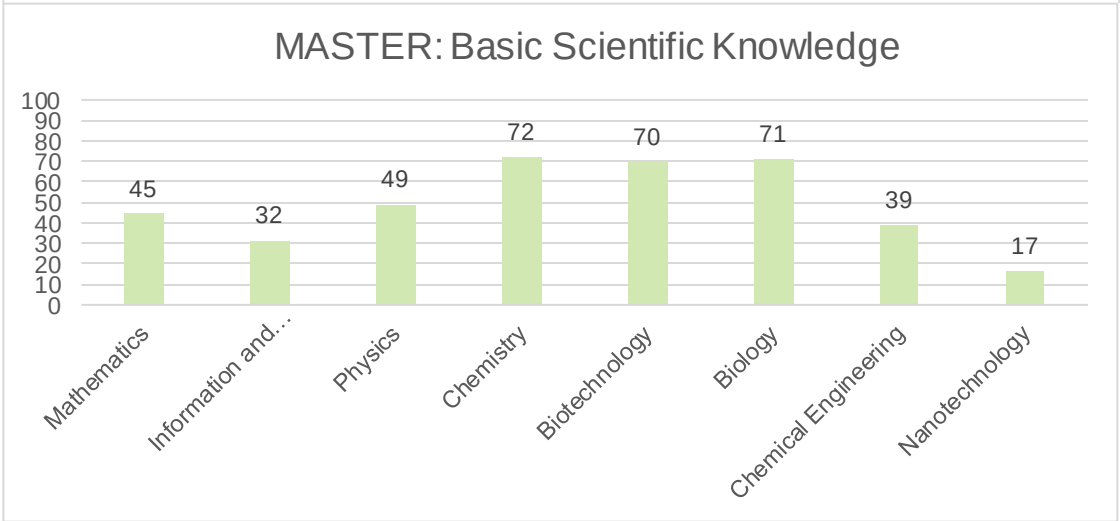
Despite this exception, comparing the different sub-competencies within the level of significance for each one, it is possible to define two patterns in regards to *Basic Scientific Knowledge*:

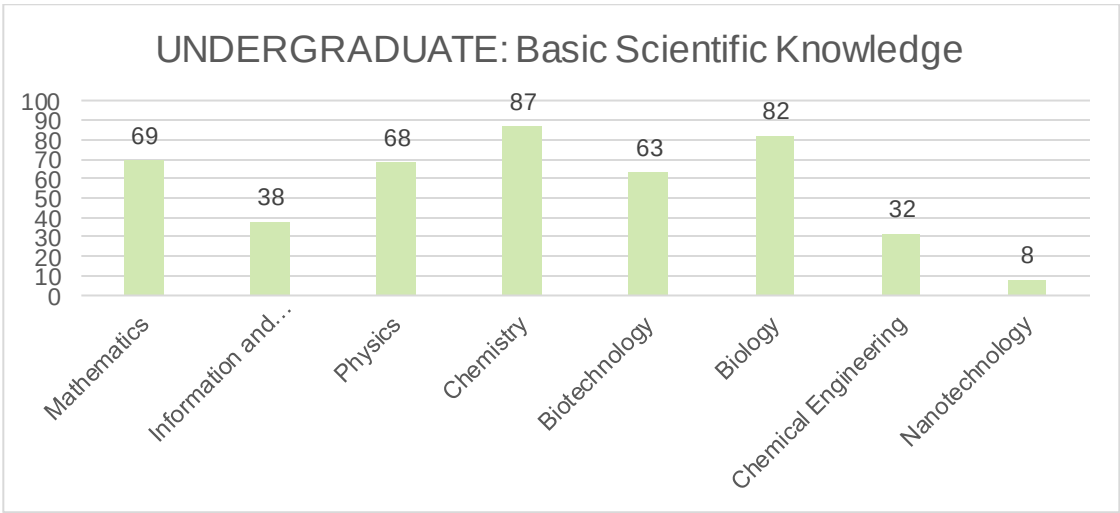
- The first pattern is related to the highest education level –PhD and Master–. Both educational levels identify *Chemistry*, *Biotechnology* and *Biology* as three core sub-competences.
- The second one is related to lower educational levels –Undergraduate and VET- For these two education levels, *Physics and Maths* join *Chemistry*, *Biotechnology* and *Biology* as key sub-competencies although it is interesting to focus the attention on the level of significance. This is higher for Undergraduate than for VET. The information sources identify a lower rating on all the sub-competencies for VET level as compared to Undergraduate.

The following figure represents the distribution of sub-competences in percentages normalised by the number of actual responses for this competence at each educational level:

- 67 PhD programmes out of 111 total PhD programmes analysed address this competence.
- 256 Master's programmes out of 417 total Master's programmes analysed address this competence.
- 228 Undergraduate programmes out of 316 total Undergraduate programmes analysed address this competence.
- 49 VET programmes out of 68 total VET programmes analysed address this competence.


PhD: Basic Scientific Knowledge
100
90
80
70
60
50
40
30
20
10
0
33
24
49
72
67
67
34
12
Mathematics
Information and…
Physics
Chemistry
Biotechnology
Biology
Chemical Engineering
Nanotechnology


MASTER: Basic Scientific Knowledge
100
90
80
70
60
50
40
30
20
10
0
45
32
49
72
70
71
39
17
Mathematics
Information and…
Physics
Chemistry
Biotechnology
Biology
Chemical Engineering
Nanotechnology


UNDERGRADUATE: Basic Scientific Knowledge
100
90
80
70
60
50
40
30
20
10
0
69
38
68
87
63
82
32
8
Mathematics
Information and…
Physics
Chemistry
Biotechnology
Biology
Chemical Engineering
Nanotechnology

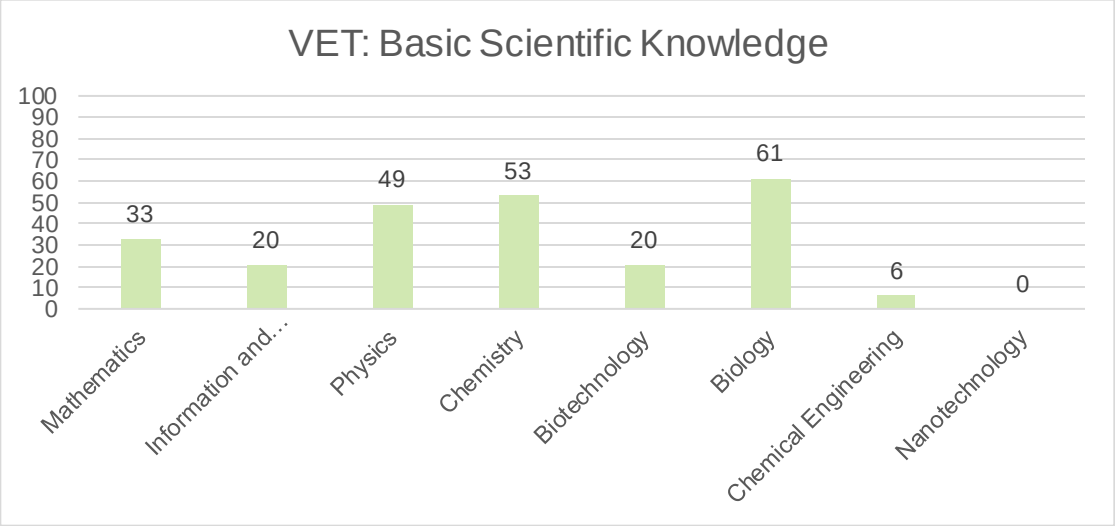


Figure 26: Basic Scientific Knowledge sub-competences at the four educational levels.

3.6.1.9. Rules and Regulations:

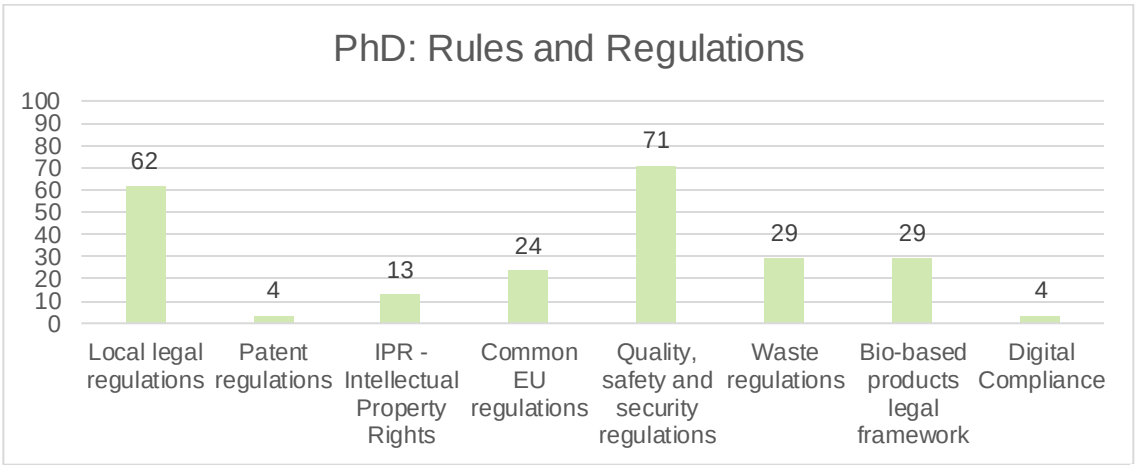
In the analysis of the *Rules and Regulations* competences, we observe that *Quality*, and *Local regulations* sub-competences are highly represented at each level, while, *Digital compliance* and *Patent regulations* are not.

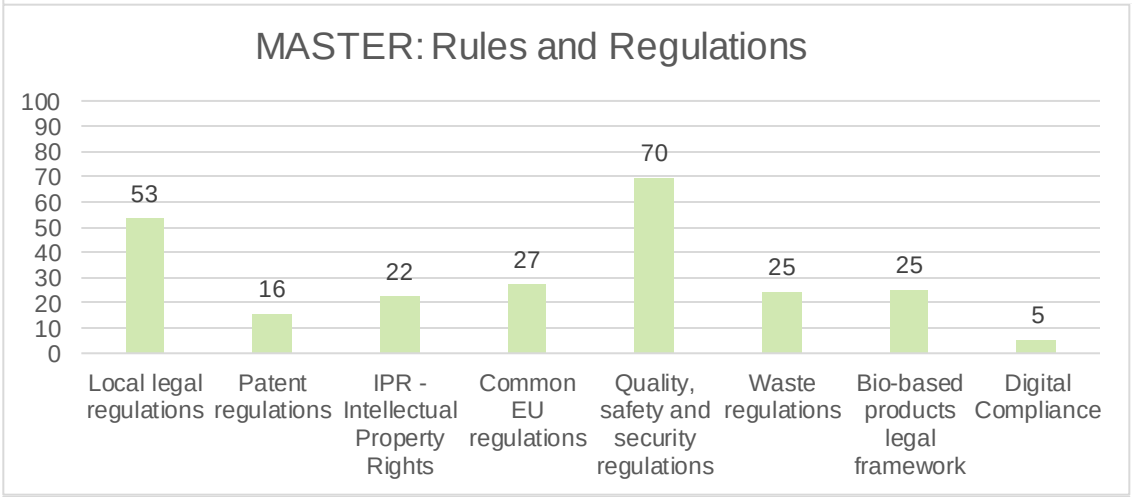
Figure 27 shows the results on the educational levels required for the development of the *Rules and Regulations* competences and sub-competences at the four educational levels.

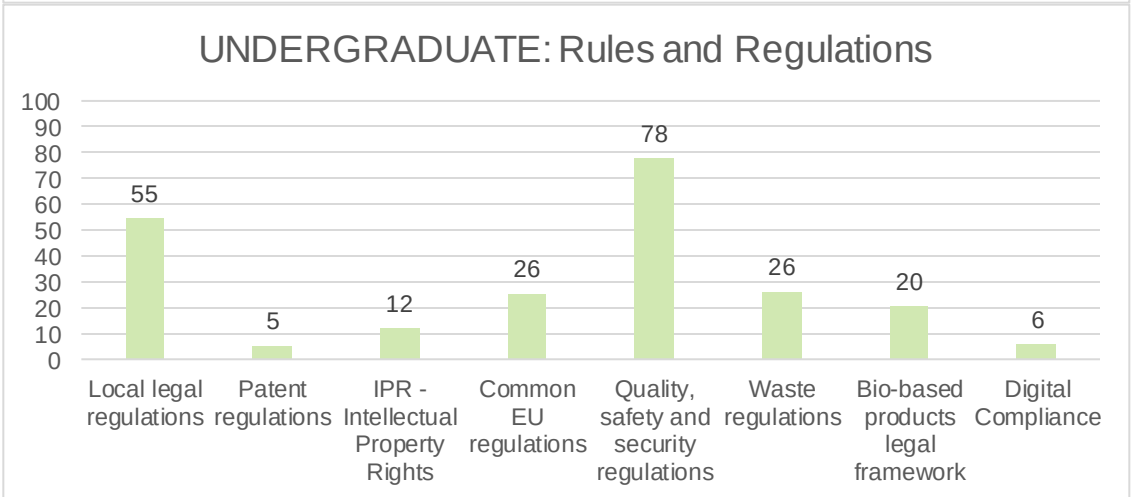
- Sub-competences associated to *Rules and Regulations* discriminate against each other, generating a very diverse priority pattern, although among the educational levels no significant differences are observed.
- Aspects related to *Quality, safety and security regulations* are considered necessary for all professionals regardless of their educational level, since it is a dimension that has an impact on all workers in all organisations.
- When analysing this competence at VET level, three sub-competences are not represented: *Patent regulations, Intellectual property rights and Digital compliance.*

The following figure represents the distribution of sub-competences in percentages normalised by the number of actual responses for this competence at each educational level:

- 55 PhD programmes out of 111 total PhD programmes analysed address this competence.
- 187 Master's programmes out of 417 total Master's programmes analysed address this competence.
- 152 Undergraduate programmes out of 316 total Undergraduate programmes analysed address this competence.
- 41 VET programmes out of 68 total VET programmes analysed address this competence.


PhD: Rules and Regulations
100
90
80
70
60
50
40
30
20
10
0
62
4
13
24
71
29
29
4
Local legal regulations
Patent regulations
IPR - Intellectual Property Rights
Common EU regulations
Quality, safety and security regulations
Waste regulations
Bio-based products legal framework
Digital Compliance


MASTER: Rules and Regulations
100
90
80
70
60
50
40
30
20
10
0
53
16
22
27
70
25
25
5
Local legal regulations
Patent regulations
IPR - Intellectual Property Rights
Common EU regulations
Quality, safety and security regulations
Waste regulations
Bio-based products legal framework
Digital Compliance


UNDERGRADUATE: Rules and Regulations
100
90
80
70
60
50
40
30
20
10
0
55
5
12
26
78
26
20
6
Local legal regulations
Patent regulations
IPR - Intellectual Property Rights
Common EU regulations
Quality, safety and security regulations
Waste regulations
Bio-based products legal framework
Digital Compliance

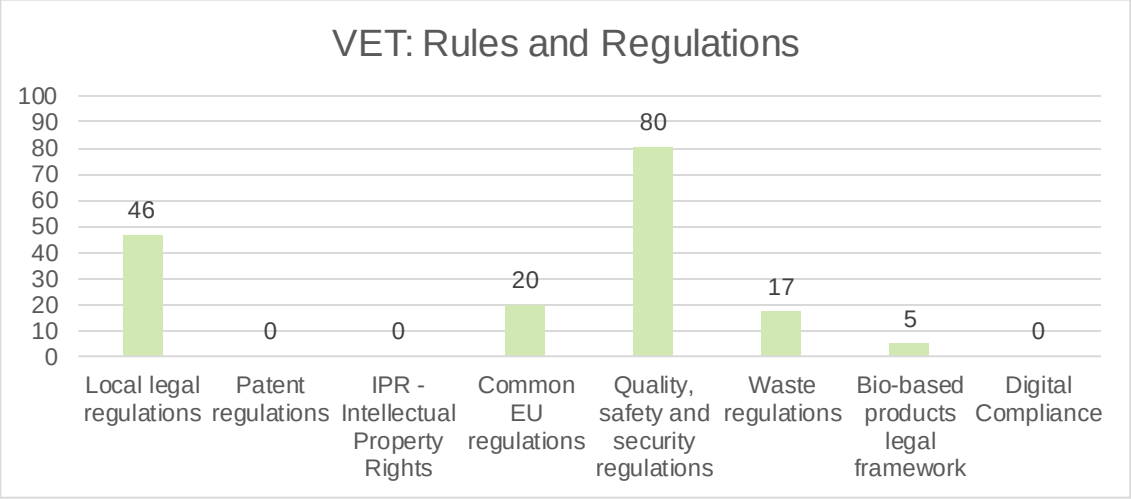


Figure 27: Rules and Regulations sub-competences at the four educational levels.

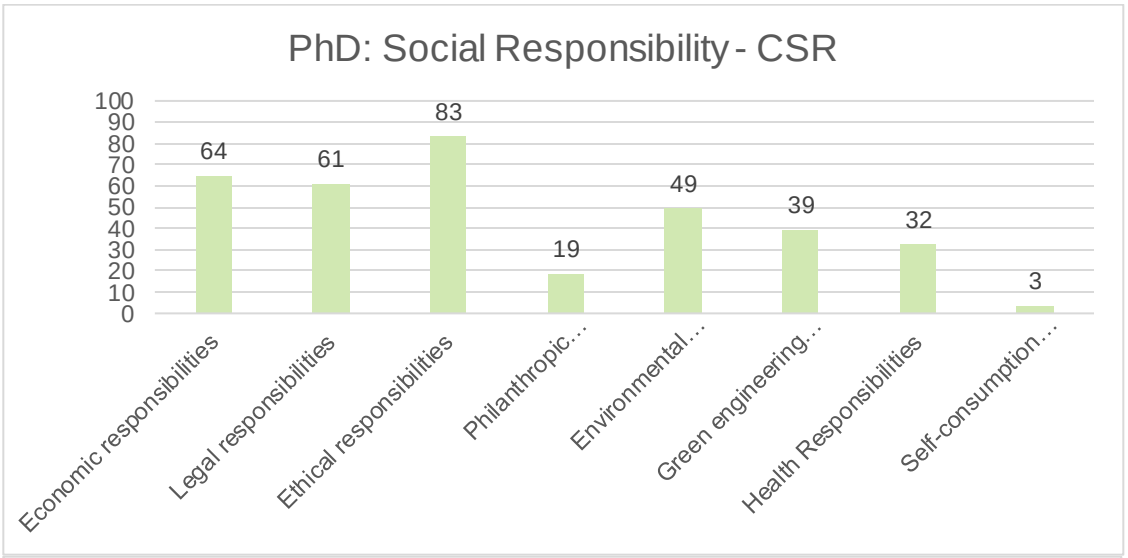
3.6.1.10. Social Responsibility – CSR:

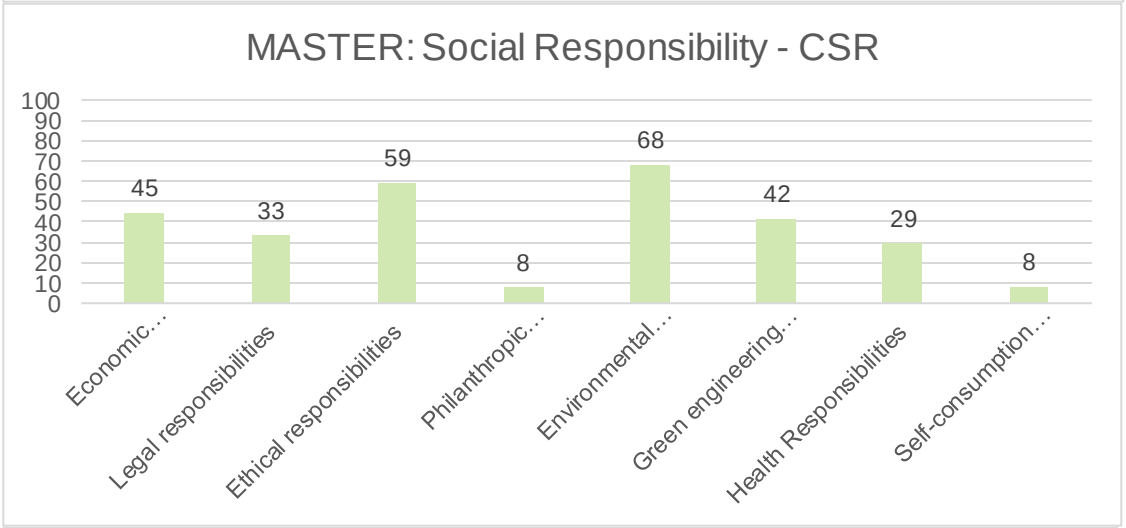
Regarding (Corporate) *Social Responsibility (CSR)* competence it is possible to identify three profiles according to the four education levels that are analysed here. The first one is related to the PhD level where *Ethical, Economic and Legal responsibilities* are identified as the core sub-competences and the group of *Environmental responsibility, Green engineering awareness and Health responsibilities* are identified as the second group of sub-competences. These groups of competences alternate for identifying the second profile defined by Master and Undergraduate level. In this second profile the E*nvironmental responsibility, Green engineering awareness and Health responsibilities* are the group of core sub-competencies and *Ethical, Economic and Legal responsibilities* are the second group of sub-competencies.

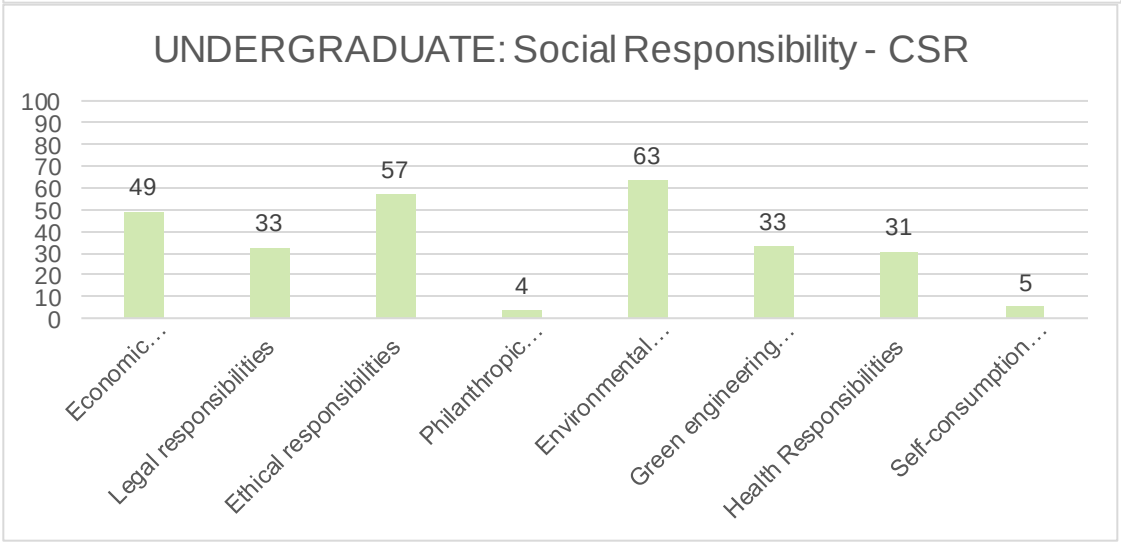
The third profile is identified by VET level that is characterized for showing the same pattern as Master and Undergraduate but with a moderate level of significance of both groups of sub-competencies. Likewise, it is interesting to focus on P*hilanthropic responsibilities* and *Self-consumption energies*, which are valued as the less significant sub-competencies at all the educational levels.

The following figure represents the distribution of sub-competences in percentages normalised by the number of actual responses for this competence at each educational level:

- 59 PhD programmes out of 111 total PhD programmes analysed address this competence.
- 226 Master's programmes out of 417 total Master's programmes analysed address this competence.
- 153 Undergraduate programmes out of 316 total Undergraduate programmes analysed address this competence.
- 25 VET programmes out of 68 total VET programmes analysed address this competence.


PhD: Social Responsibility - CSR
100
90
80
70
60
50
40
30
20
10
0
64
61
83
19
49
39
32
3
Economic responsibilities
Legal responsibilities
Ethical responsibilities
Philanthropic…
Environmental…
Green engineering…
Health Responsibilities
Self-consumption…


MASTER: Social Responsibility - CSR
100
90
80
70
60
50
40
30
20
10
0
45
33
59
8
68
42
29
8
Economic…
Legal responsibilities
Ethical responsibilities
Philanthropic…
Environmental…
Green engineering…
Health Responsibilities
Self-consumption…


UNDERGRADUATE: Social Responsibility - CSR
100
90
80
70
60
50
40
30
20
10
0
49
33
57
4
63
33
31
5
Economic…
Legal responsibilities
Ethical responsibilities
Philanthropic…
Environmental…
Green engineering…
Health Responsibilities
Self-consumption…

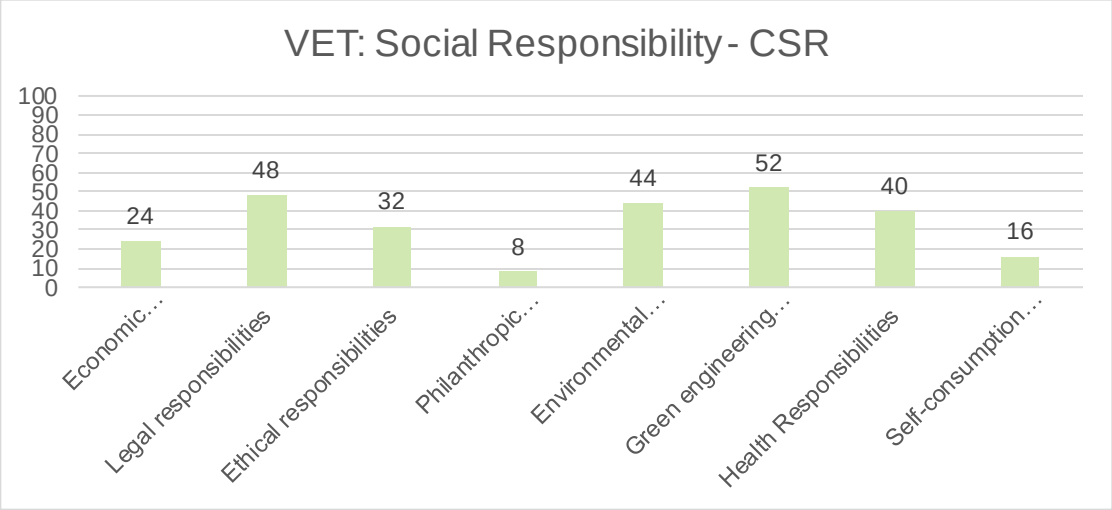


Figure 28: Social Responsibility - CSR sub-competences at the four educational levels.

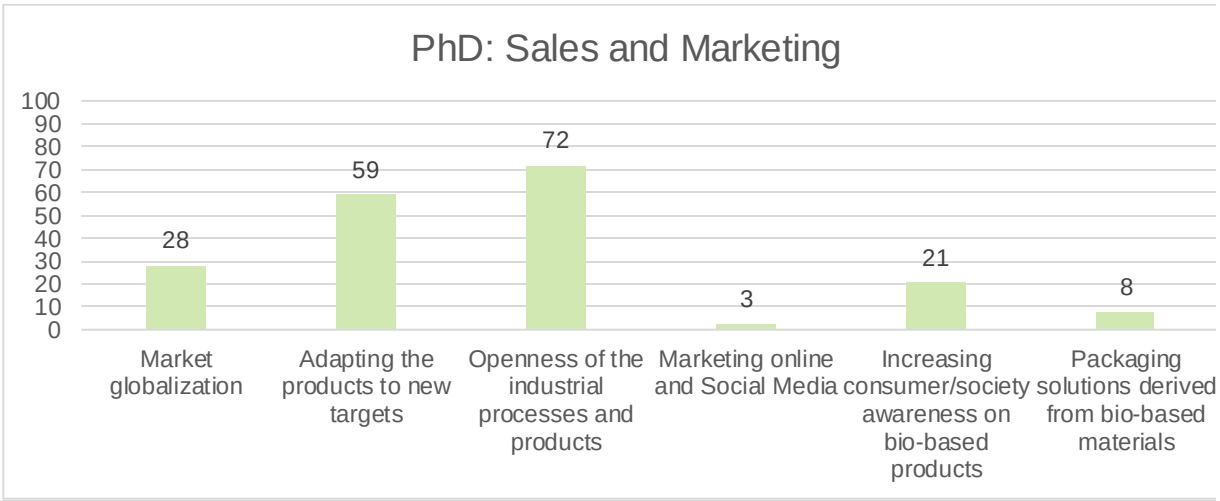
3.6.1.11 Sales and Marketing:

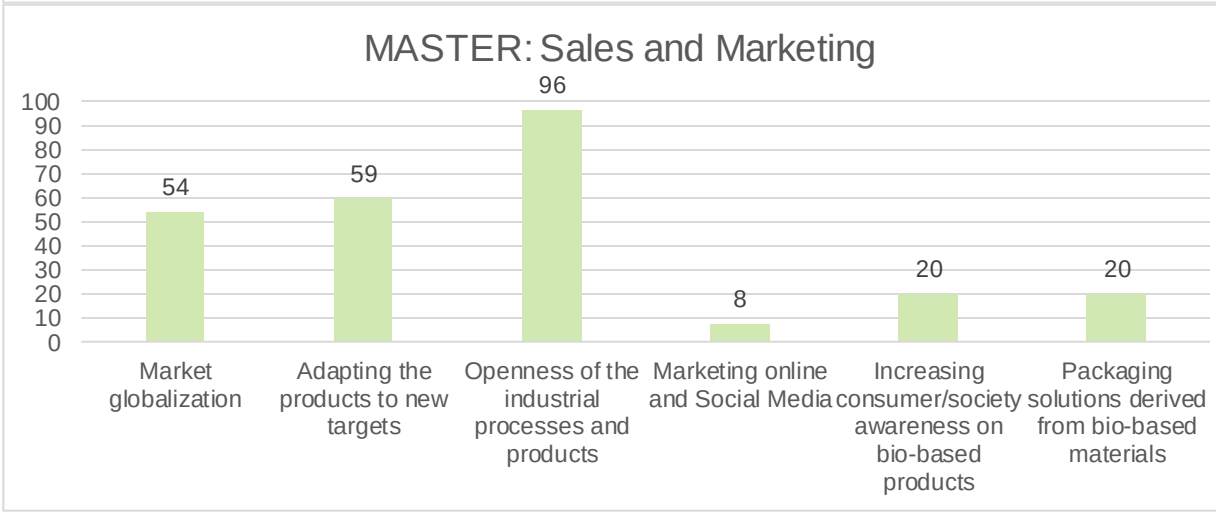
Regarding Sales and Marketing competence, it is possible to identify two profiles according to the four education levels that are analysed here. The first one is related to University level integrated by PhD, Master and Undergraduate. The second one is related to VET level.

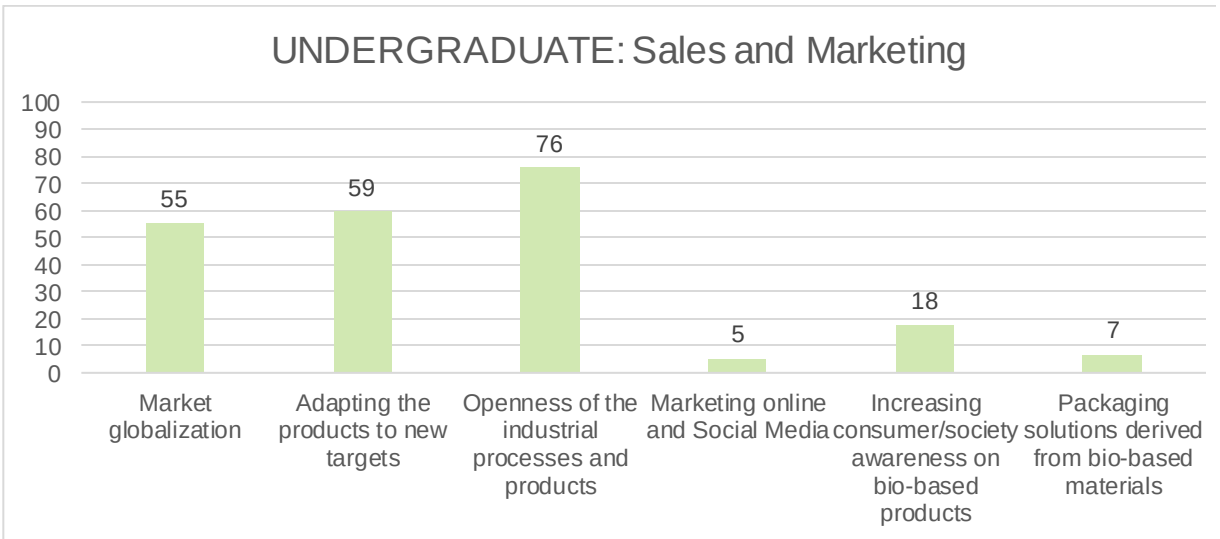
University level, in its three types of studies, identifies *Openness of the industrial processes and products, Adapting the products to new targets* and *Market globalization* as the core of sub-competences while for VET level the most significant one is *Adapting the products to new targets*. Likewise, VET profile does not identify sub-competence like *Increasing consumer/society awareness on bio-based products* and *Packaging solutions derived from bio-based materials*, sub-competences that are identified by the other educational level although less significantly.

The following figure represents the distribution of sub-competences in percentages normalised by the number of actual responses for this competence at each educational level:

- 39 PhD programmes out of 111 total PhD programmes analysed address this competence.
- 106 Master's programmes out of 417 total Master's programmes analysed address this competence.
- 74 Undergraduate programmes out of 316 total Undergraduate programmes analysed address this competence.
- 14 VET programmes out of 68 total VET programmes analysed address this competence.


PhD: Sales and Marketing
100
90
80
70
60
50
40
30
20
10
0
28
59
72
3
21
8
Market globalization
Adapting the products to new targets
Openness of the industrial processes and products
Marketing online and Social Media
Increasing consumer/society awareness on bio-based products
Packaging solutions derived from bio-based materials


MASTER: Sales and Marketing
100
90
80
70
60
50
40
30
20
10
0
54
59
96
8
20
20
Market globalization
Adapting the products to new targets
Openness of the industrial processes and products
Marketing online and Social Media
Increasing consumer/society awareness on bio-based products
Packaging solutions derived from bio-based materials


UNDERGRADUATE: Sales and Marketing
100
90
80
70
60
50
40
30
20
10
0
55
59
76
5
18
7
Market globalization
Adapting the products to new targets
Openness of the industrial processes and products
Marketing online and Social Media
Increasing consumer/society awareness on bio-based products
Packaging solutions derived from bio-based materials

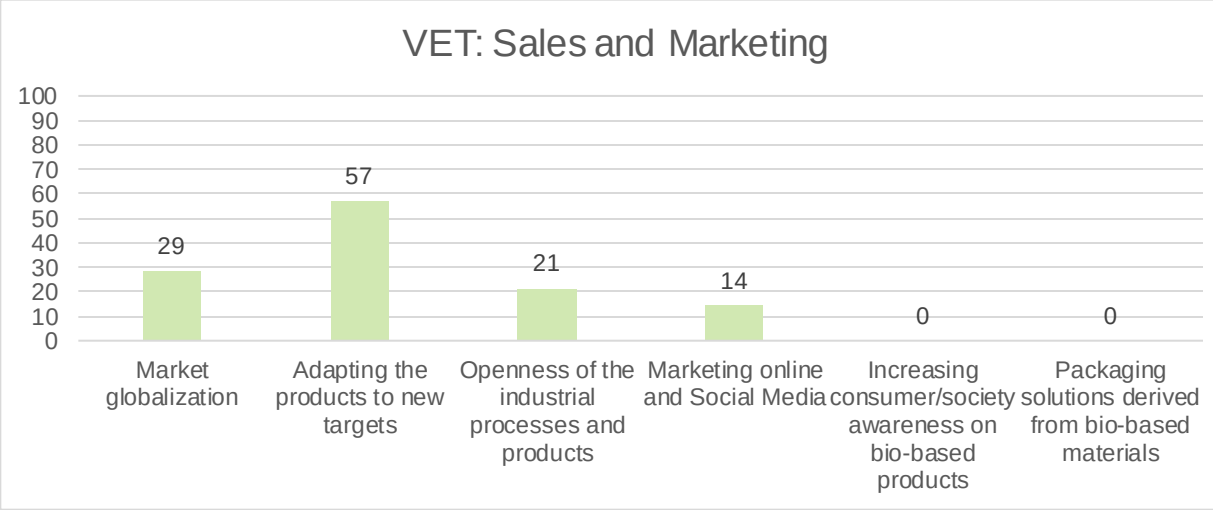
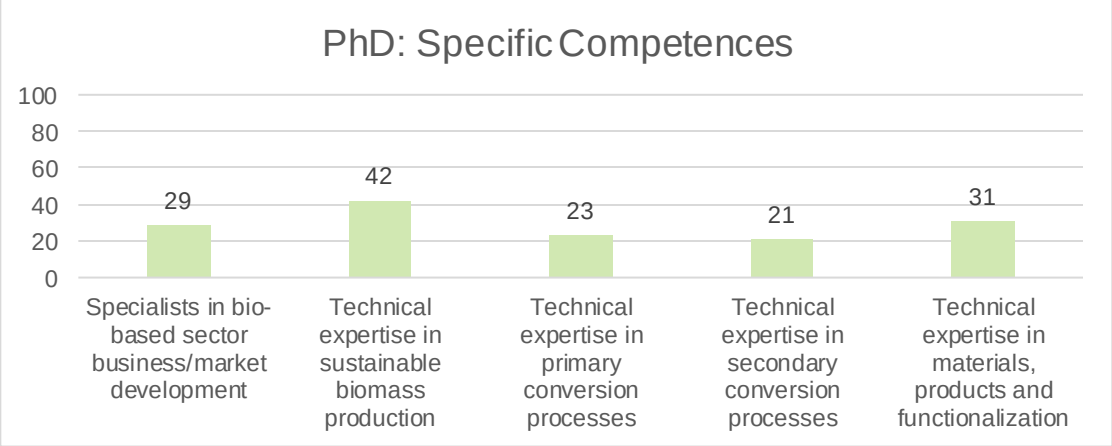


Figure 29: Sales and Marketing sub-competences at the four educational levels.

3.6.2 Specific Competences for Bio-based Industries

Regarding the presence of specific competences for Bio-based Industries in curricula, they are more present in PhDs and Masters' degrees, unlike VETs programmes, where a clear misrepresentation can be appreciated, except for a few exceptions *like Methods for efficient and cost-effective biomass' production*. Undergraduate programmes are likely to stand in the middle of both extremes, since all specific competences are mostly represented, yet at lower percentage. Yet, in general terms, it is worth mentioning that the presence of specific competences across all educational levels is much lower than the presence of the general competences.



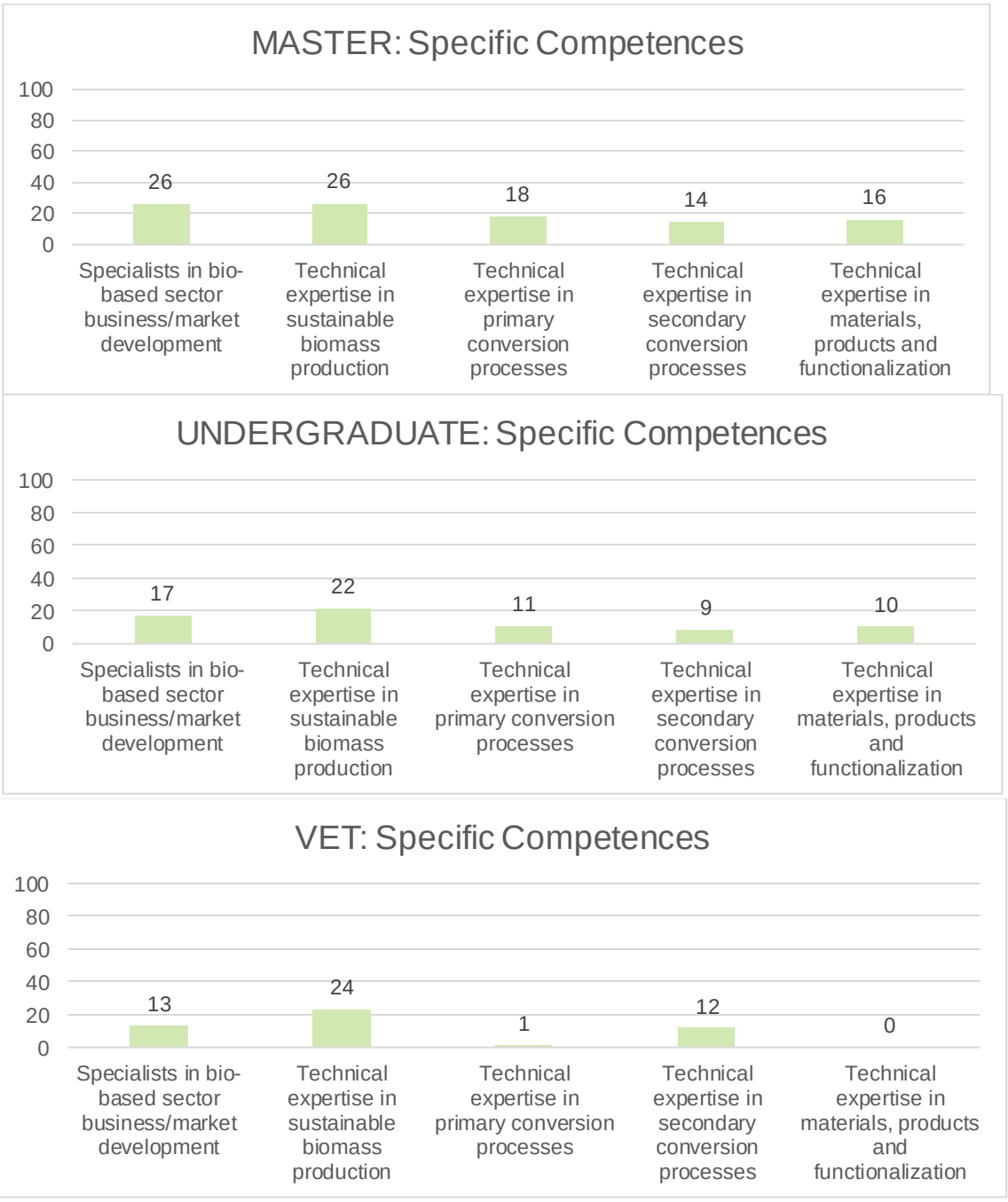


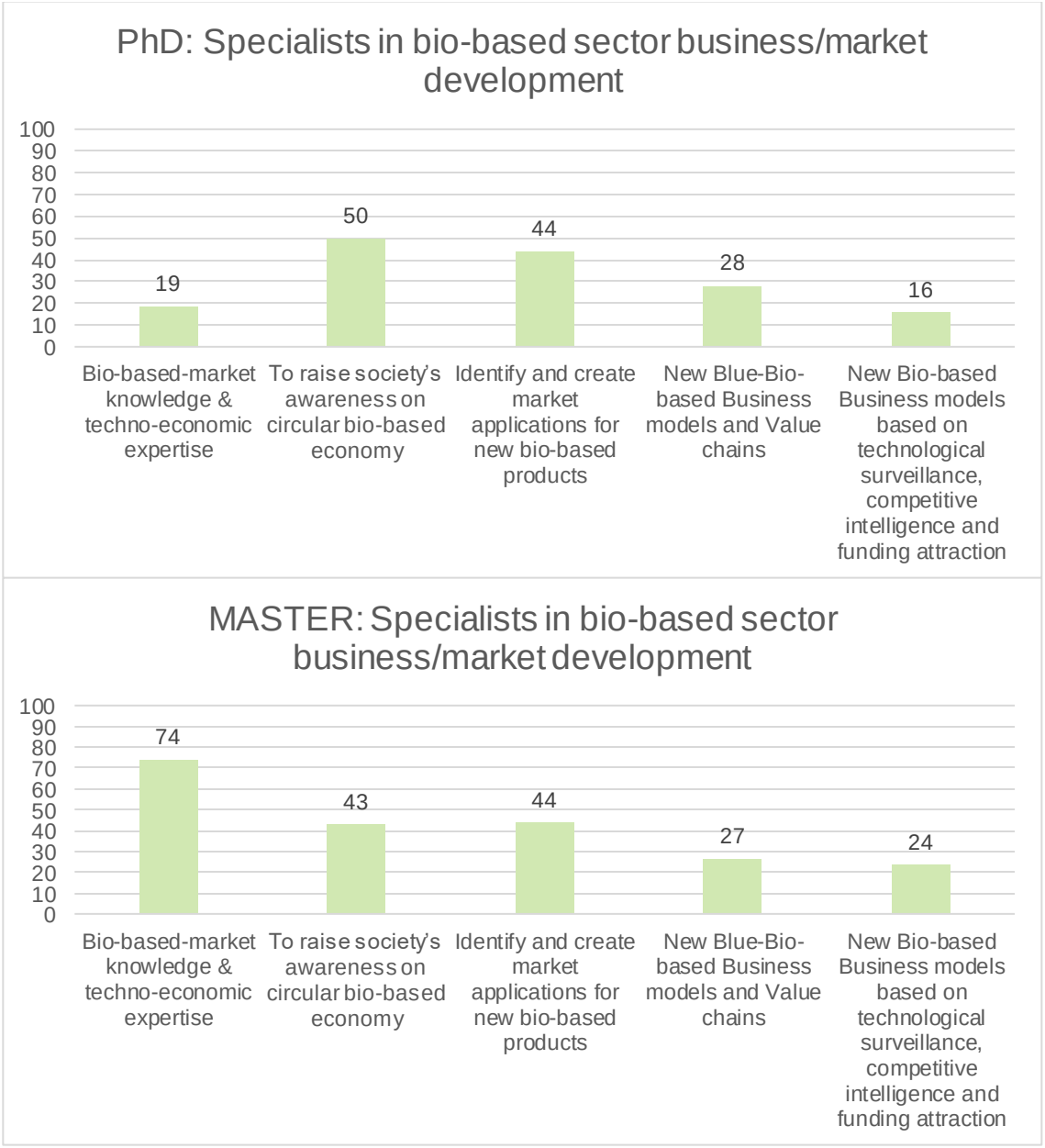
Figure 30: Specific Competences and sub-competences at the four educational levels

3.6.2.1. Specialists in bio-based sector business/market development:

Regarding *Specialist in bio-based sector business/market development* competence, it is relevant to say that all the sub-competences are represented at all the educational levels analysed, except for VET, where less programmes where available to be analysed. It is interesting to notice that both at PhD and VET level, the most remarkable sub-competence is *To raise socitey's awareness on circular bio-based economy.*

The following figure represents the distribution of sub-competences in percentages normalised by the number of actual responses for this competence at each educational level:

- 32 PhD programmes out of 111 total PhD programmes analysed address this competence.
- 109 Master's programmes out of 417 total Master's programmes analysed address this competence.
- 55 Undergraduate programmes out of 316 total Undergraduate programmes analysed address this competence.
- 9 VET programmes out of 68 total VET programmes analysed address this competence.



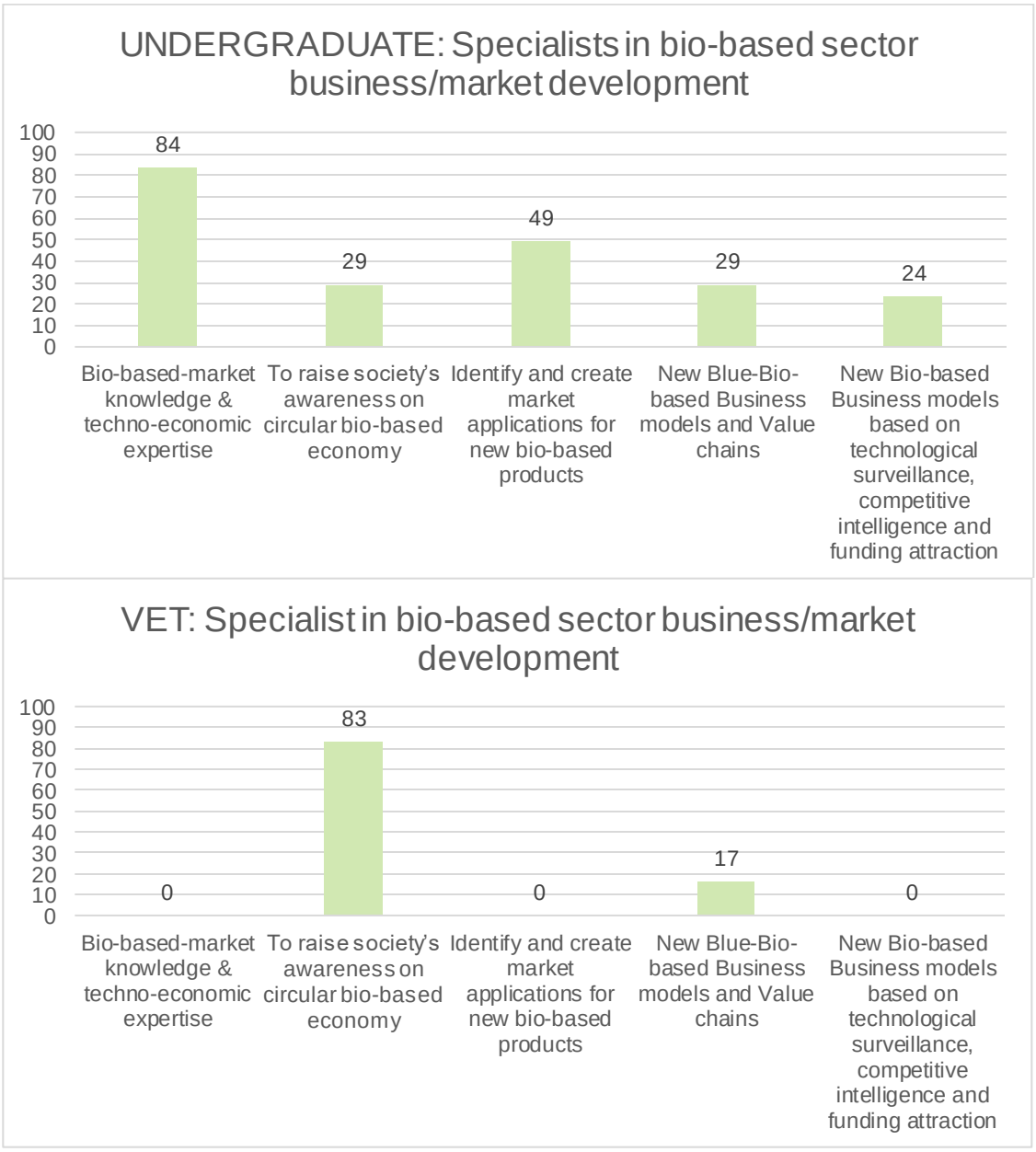


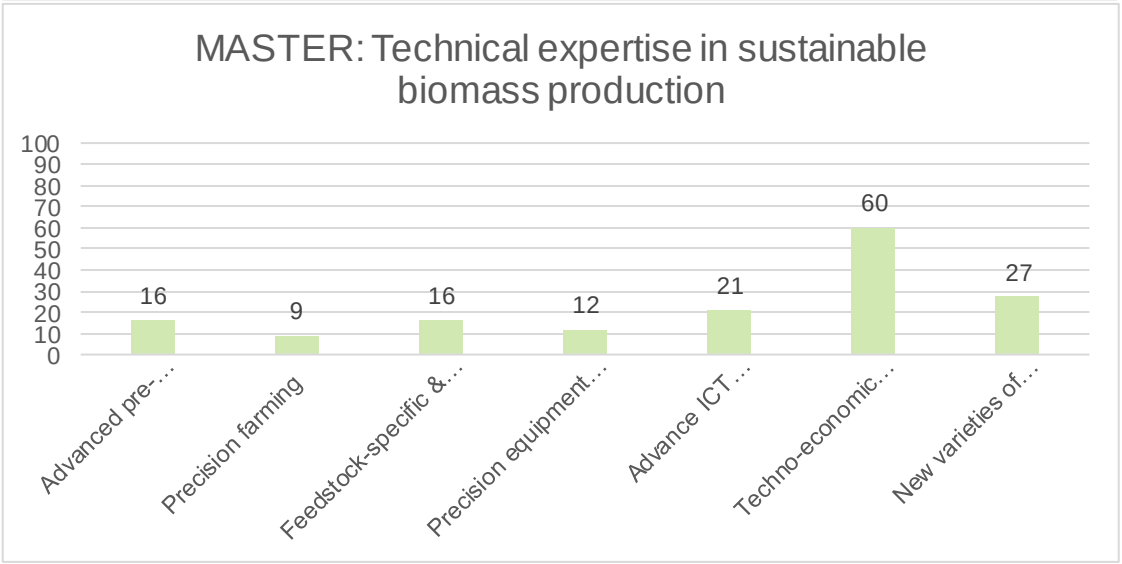
Figure 31: Specialist in bio-based sector business/market development sub-competences at the four educational levels.

3.6.2.2. Technical expertise in sustainable biomass production:

Regarding the *Technical expertise in sustainable biomass production* competence category, a homogenous profile is identified: at all educational levels, the most taught sub-competence is the *Techno-economic assessment of processes, biorefineries and bio-based value chains.*

Figure 32 represents the distribution of sub-competences in percentages normalised by the number of actual responses for this competence at each educational level:

- 47 PhD programmes out of 111 total PhD programmes analysed address this competence.
- 110 Master's programmes out of 417 total Master's programmes analysed address this competence.
- 68 Undergraduate programmes out of 316 total Undergraduate programmes analysed address this competence.



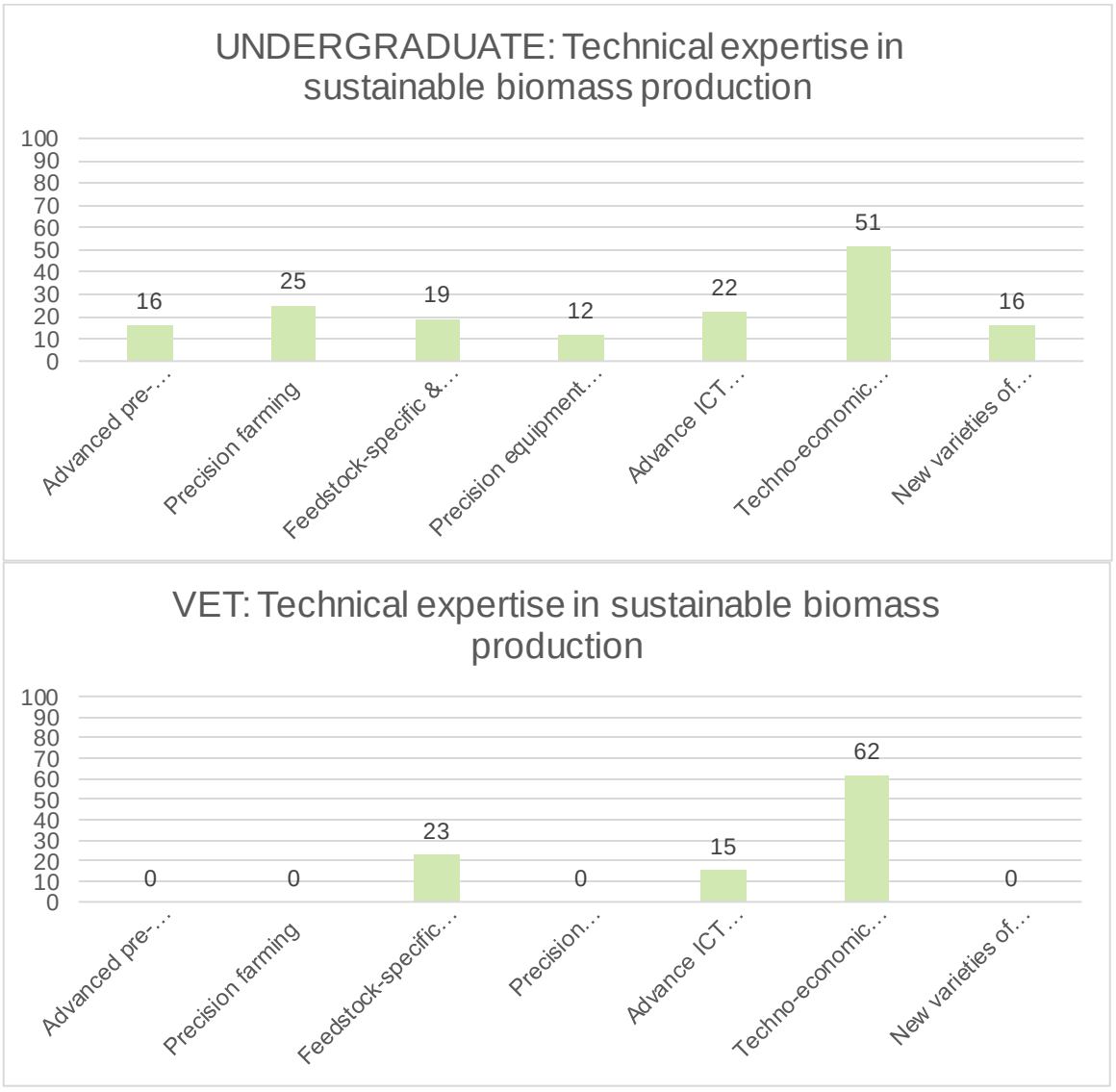


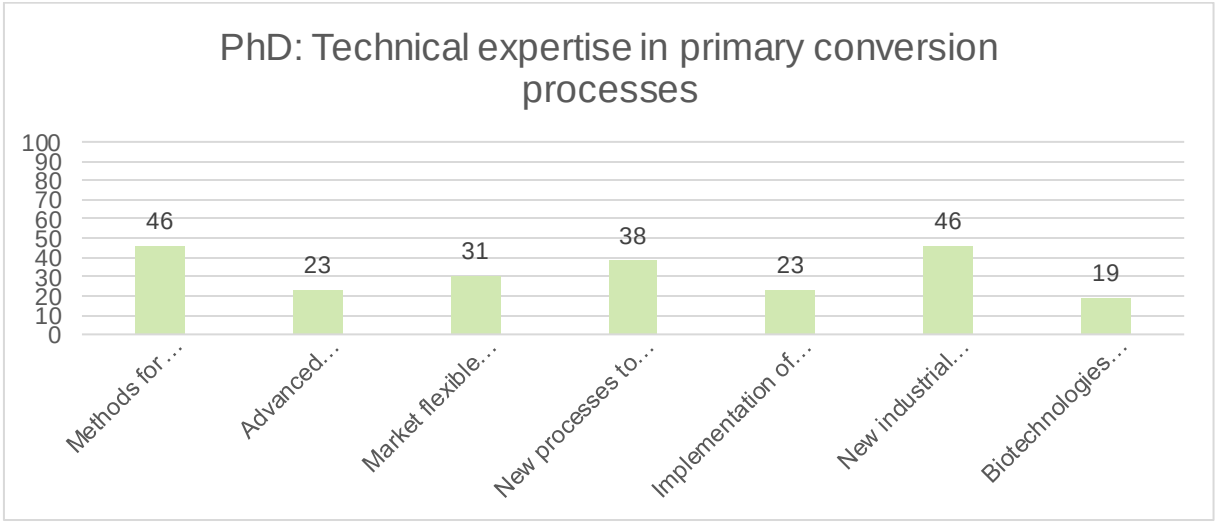
Figure 32: Technical expertise in sustainable biomass production sub-competences at the four educational levels.

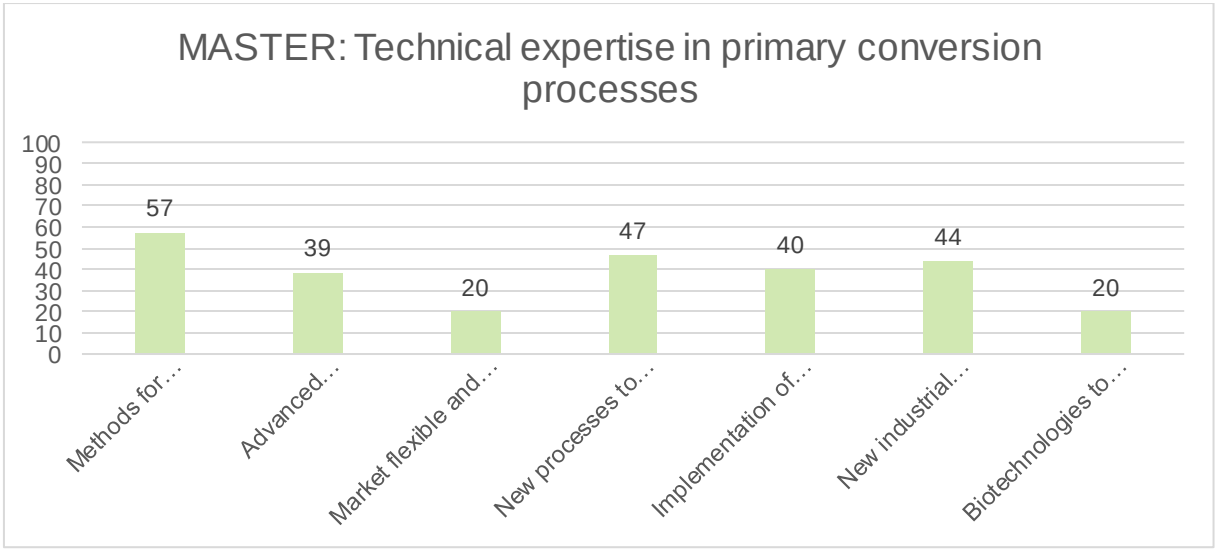
3.6.2.3. Technical expertise in primary conversion processes:

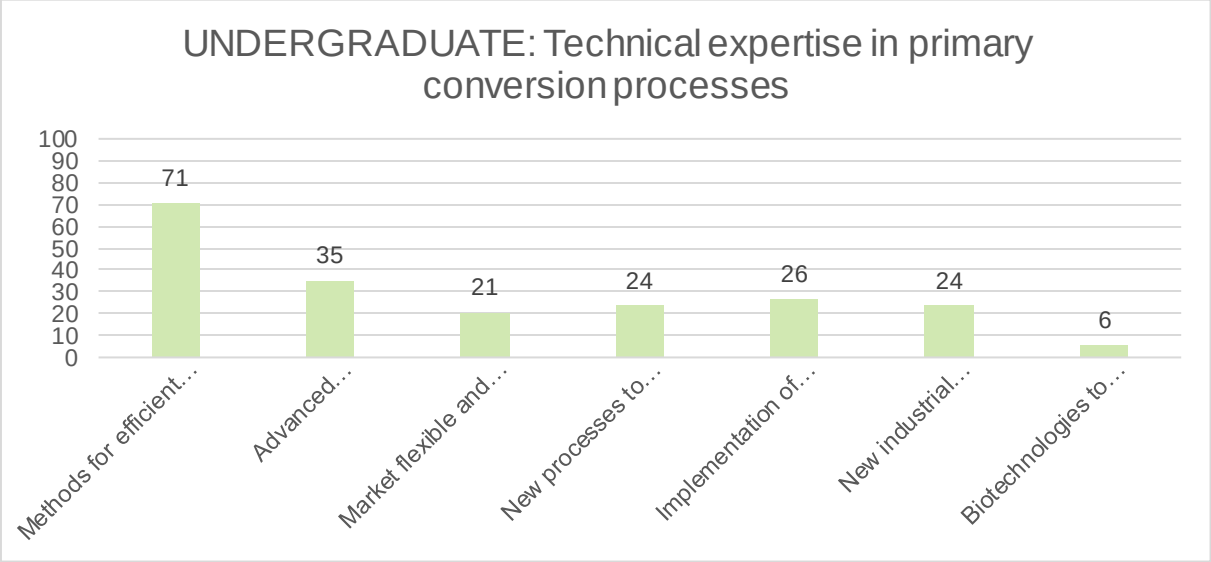
Regarding Technical expertise in primary conversion processes, the same profile is observed at PhD; Master and Undergraduate level. As it is expected, due to this very technical expertise competence, it is misrepresented in VET programmes.

Figure 33 represents the distribution of sub-competences in percentages normalised by the number of actual responses for this competence at each educational level:

- 26 PhD programmes out of 111 total PhD programmes analysed address this competence.
- 75 Master's programmes out of 417 total Master's programmes analysed address this competence.
- 34 Undergraduate programmes out of 316 total Undergraduate programmes analysed address this competence.
- 1 VET programmes out of 68 total VET programmes analysed address this competence.







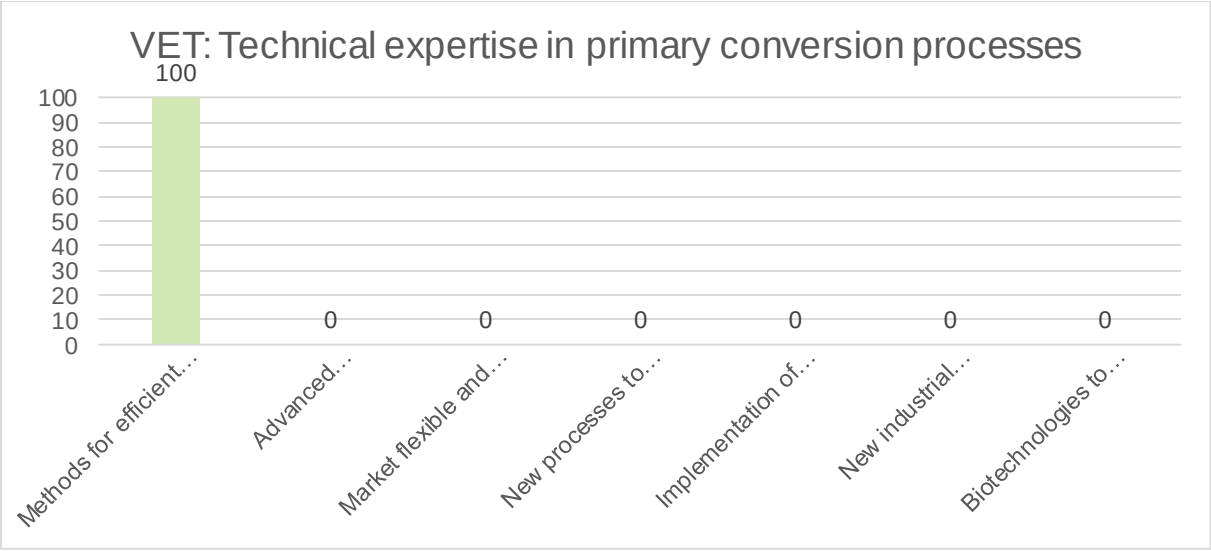


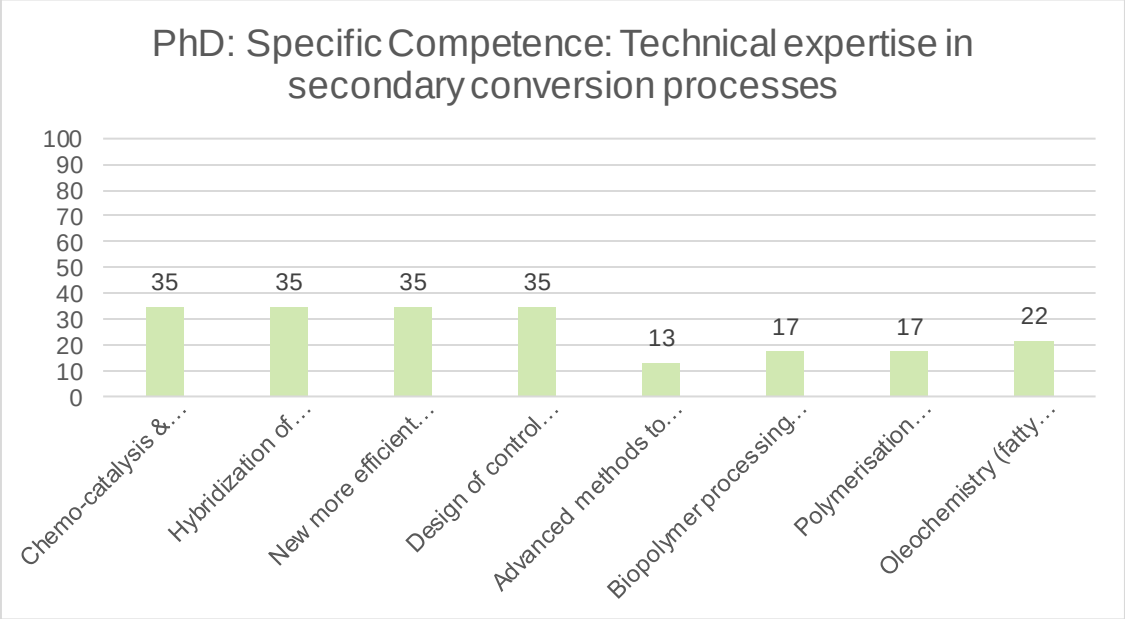
Figure 33: Technical expertise in primary conversion processes sub-competences at the four educational levels.

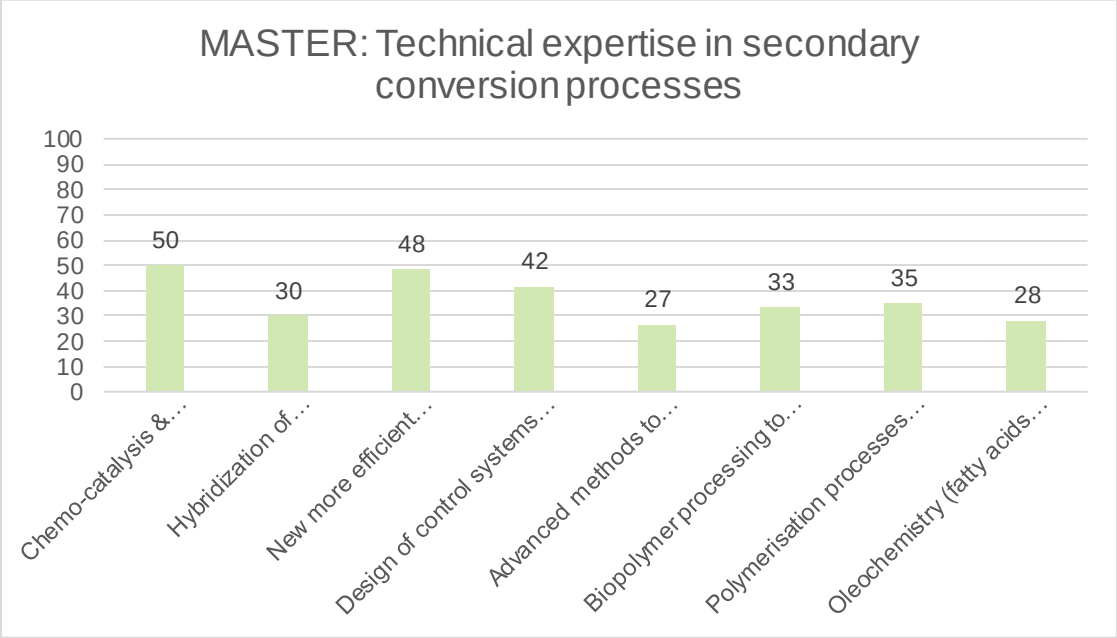
3.6.2.4. Technical expertise in secondary conversion processes:

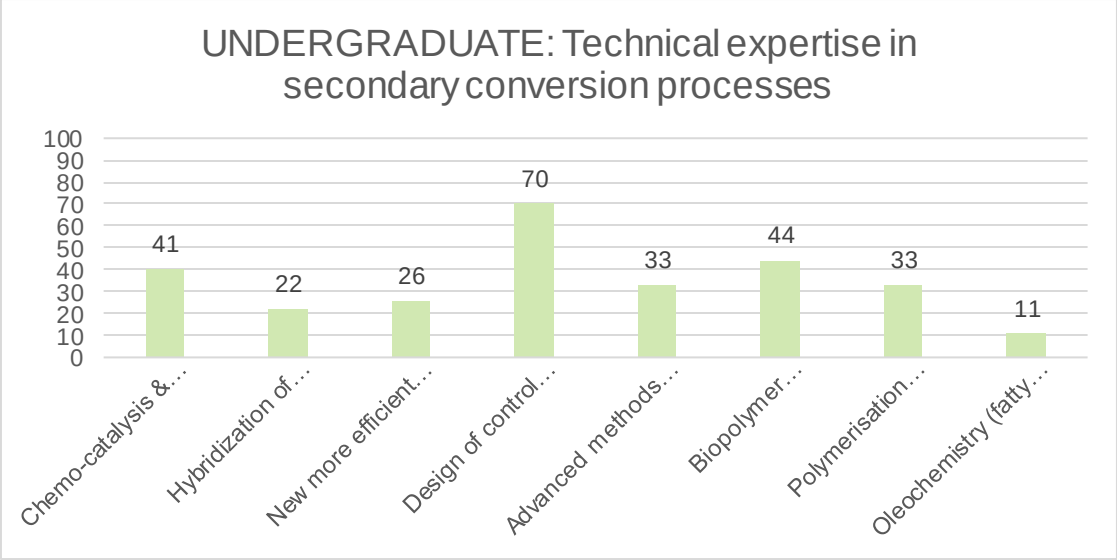
This very proficient technical expertise competences are more represented at Master's and Undergraduate levels. When tackling sub-competences identification, all the sub-competences are represented in the three highest levels, focusing on the *Design of Control of systems for robust, stable and sustainable production, quality and contaminants monitoring*. The latter sub-competence is one of the two sub-competences mentioned at VET level.

Figure 34 represents the distribution of sub-competences in percentages normalised by the number of actual responses for this competence at each educational level:

- 23 PhD programmes out of 111 total PhD programmes analysed address this competence.
- 60 Master's programmes out of 417 total Master's programmes analysed address this competence.
- 27 Undergraduate programmes out of 316 total Undergraduate programmes analysed address this competence.
- 8 VET programmes out of 68 total VET programmes analysed address this competence.




MASTER: Technical expertise in secondary conversion processes
100
90
80
70
60
50
40
30
20
10
0
50
30
48
42
27
33
35
28
Chemo-catalysis &…
Hybridization of…
New more efficient…
Design of control systems…
Advanced methods to…
Biopolymer processing to…
Polymerisation processes…
Oleochemistry (fatty acids…


UNDERGRADUATE: Technical expertise in secondary conversion processes
100
90
80
70
60
50
40
30
20
10
0
41
22
26
70
33
44
33
11
Chemo-catalysis &…
Hybridization of…
New more efficient…
Design of control…
Advanced methods…
Biopolymer…
Polymerisation…
Oleochemistry (fatty…

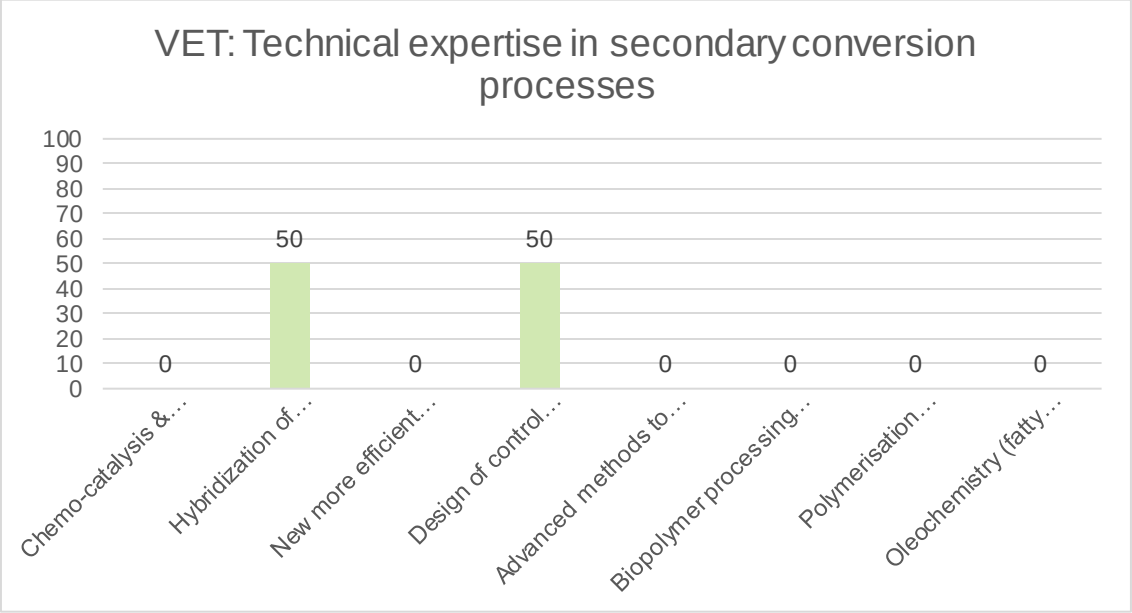


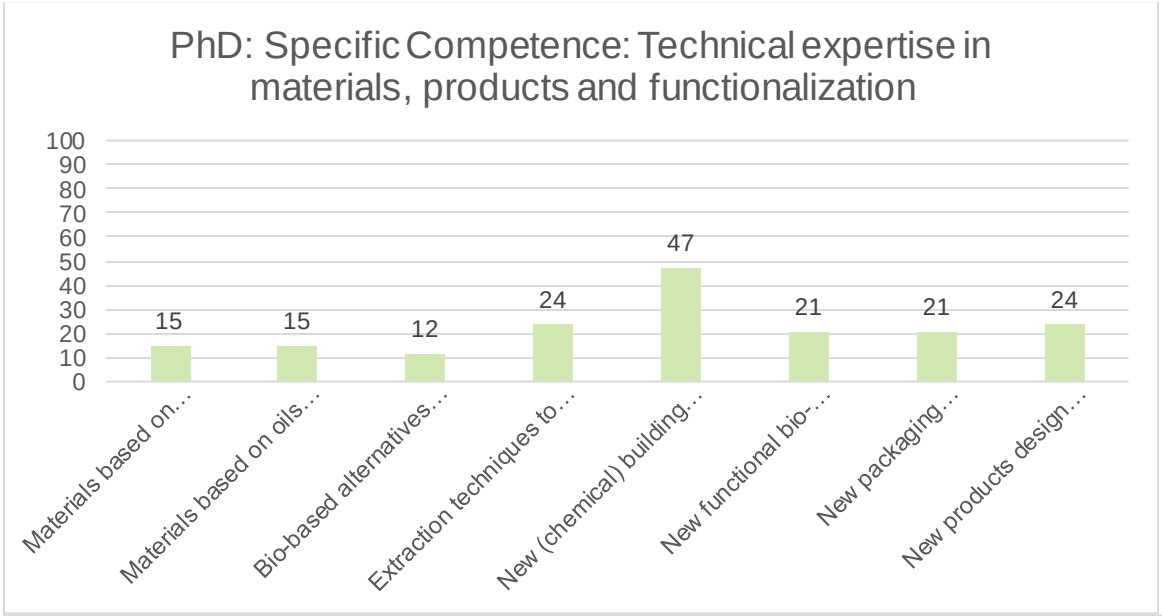
Figure 34: Technical expertise in secondary conversion processes sub-competences at the four educational levels.

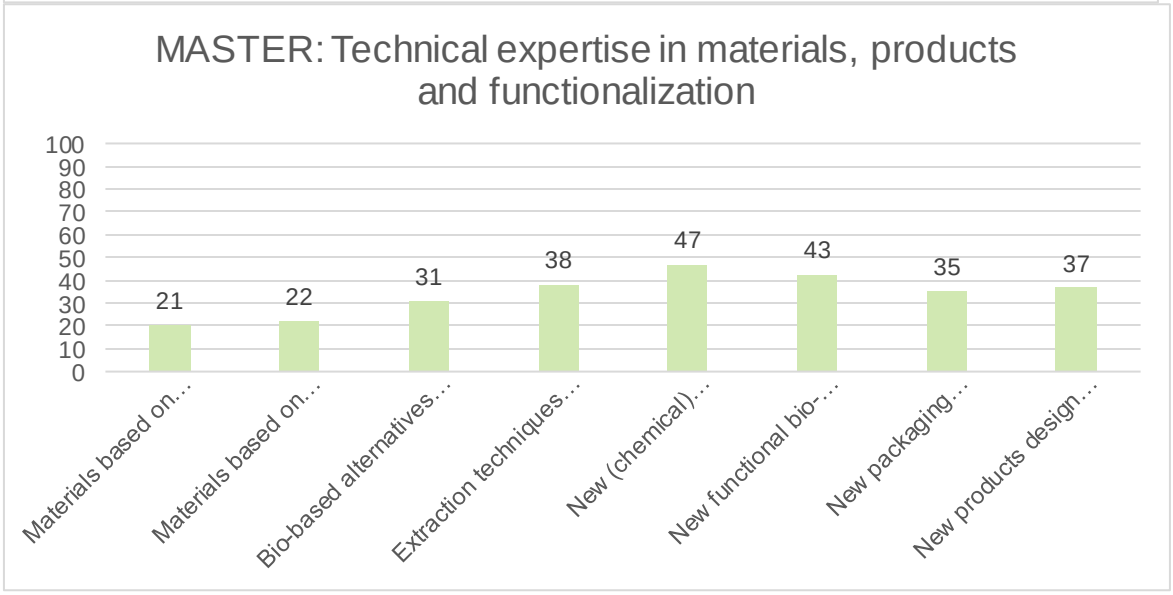
3.6.2.5. Technical expertise in materials, products and functionalization:

Regarding *Technical expertise in materials, products and functionalization*, the same profile as for the above competences is described: a homogenous pattern for PhD, Master's and Undergraduate level.

Figure 35 represents the distribution of sub-competences in percentages normalised by the number of actual responses for this competence at each educational level:

- 34 PhD programmes out of 111 total PhD programmes analysed address this competence.
- 68 Master's programmes out of 417 total Master's programmes analysed address this competence.
- 33 Undergraduate programmes out of 316 total Undergraduate programmes analysed address this competence.
- 0 VET programmes out of 68 total VET programmes analysed address this competence.





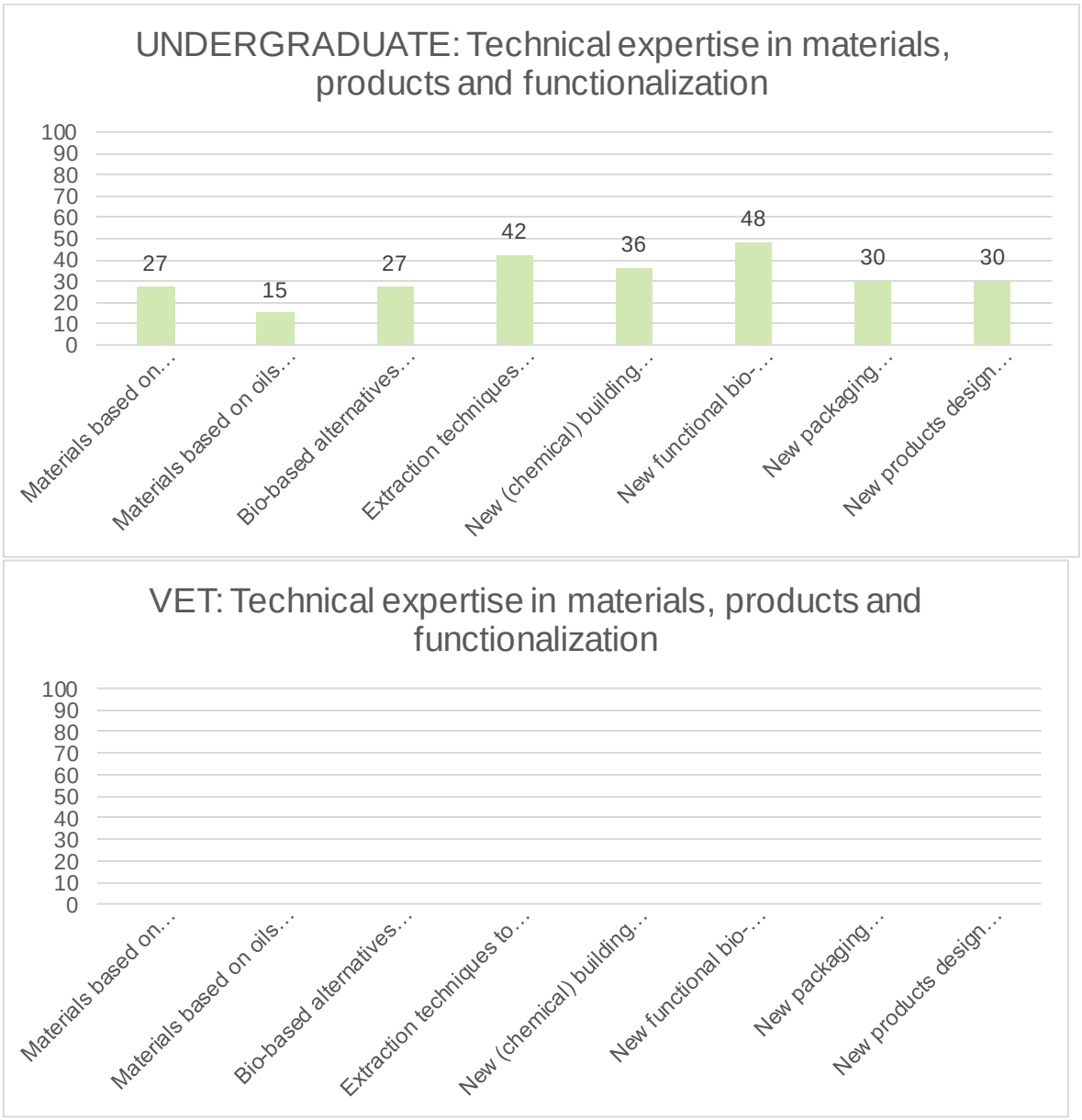


Figure 35: Technical expertise in materials, products and functionalization sub-competences at the four educational levels.

Considering the low number of programmes that address the specific competences and sub-competences considered relevant for this study, particularly at VET level, it seems reasonable to include in this section additional specific competences identified by informants when analysing the different programmes. In the case of VET, the relevance of these additional specific competences identified is comparable to the ones proposed at the EPT. Figure 36 shows the distribution in percentages of additional specific sub-competences identified by VET informants:

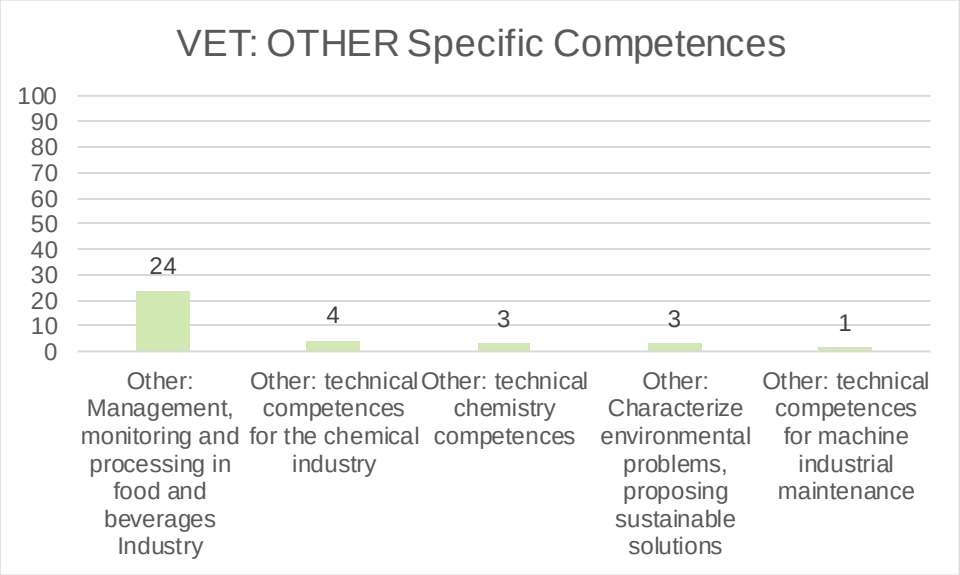


Figure 36: Other specific competences and sub-competences at VET level

OTHER SPECIFIC COMPETENCES	NUMBER OF VET
Other: Management, monitoring and processing in food and beverages Industry	16
Other: technical competences for the chemical industry	3
Other: technical chemistry competences	2
Other: Characterize environmental problems, proposing sustainable solutions	2
Other: technical competences for machine industrial maintenance	1

For the rest of academic levels (PhD, Master and Undergraduate) many other competences have been identified. However, their relevance seems to be lower and not comparable to the sub-competences proposed at the EPT. The following list is a compilation of those additional competences identified by informants at PhD, Master and Undergraduate levels with the number of repetitions identified:

PhD:

Food, Nutrition and Health Science	**7**
Botanical knowledge related to ideal plants for bioenergy production	5
Chemical technology	5
Forest engineering	5
Environmental processes and protection	5
Industrial Biotechnology	3
Marine Sciences	3
Bioproduct technology	3
Biosensors and nanobiosensors	3
Wood Technology	3
Sustainable Development	3
Innovative materials	2
Materials science, nanobiomaterials	2
Agricultural Ecology	2
Package Printing and Converting	2
Plant Physiology and Computational Science and Engineering	2
Fiber and polymer materials and technology	2
Anaerobic fermentation of organic material	1
Biomedical engineering and industrial biotechnology (one of the research areas)	1
Biopolymer chemistry and bio-nanotechnology	1
Cathalitic Reactors Engineering	1
Design and protein production for nanotechnologic applications	1
Enzymatic, chemical and physical modification of polysaccharides	1
Microalgae biotechnology	1
Microbiology	1
New experimental methods for characterization of polysaccharides	1
The Sodium/Sulfur-Balance in a Pulp Mill	1
Tissue Products and Technology	1
Use of agro-livestock by-products in agriculture	1
Valorizing biomass	1
Processing of materials (research field)	1
Product flow analysis	1
Production of fatty acids (DHA) in marine microorganisms	1
Regenerated Cellulose and Cellulose Derivatives	1

MASTER:

A general package for running a company (soft skills and management skills)	1
Advanced Chemical Engineering with Biotechnology	1
Advanced Chemical Engineering with Process Systems Engineering	1
Advanced Chemical Engineering with Structured Product Engineering	1
Agricultural development	8
Analysis and Design of Chemical and Biological Reactors	1
Analytical capacity to distinguish among biomass types in order to look for the appropriate energy outcome	1
Application of the different omics (genomics, transcriptomics, etc ...) to the resolution of microbiologicalproblems	1
Applied nanotechnology	1
Apply biotechnological cell factory methods to plants and fungi to obtain new products	1
Apply methods, tools and strategies to develop biotechnological processes and products with energy-saving and sustainability criteria	1
Autonomous photovoltaic system engineering	1
Bioactive compounds extraction, purification and definition	1
Biocatalysis and Biosensors design	1
Biochemistry	1
Bioenergy	12
Bio-informatics and modelling	9
Biologic systems Engineering	1
Biomass refining (major)	1
Bionanotechnology	3
BioPAT methodology	1
Bioremediation	3
Biosensors	4
Biotechnology and bioengineering and bioproducts	5
Breeding of aquatic species	1
Carbon Cycling and Climate Change	1
Catalysis	1
Chemicals from renewable sources: Exploitation of biomass. Biofuels.	5
Climate Change, Impact and Action Strategies	1
Colloid and polymer chemistry	1
Company creation, circular business modelling, management	8
Conventional organic solvent alternatives	1

Cost-benefit analysis	1
Decision making	1
Define and model the control systems of complex chemical-physical processes.	1
Design a research and educational innovation project to solve a problem about the teaching and learning of some subject of the science and technology curriculum.	2
Design and synthesize new organic, inorganic or organometallic molecules of industrial and technological interest.	1
Design of biological systems from the information obtained in their characterization.	1
Design or select individual process equipment, particularly in the area of separation processes and chemical reactors.	1
Develop biotechnological processes and products with energy-saving and sustainability criteria	1
Develop new ways to improve existing food and animal feed crops (and to develop novel crops)	1
Development in agriculture and forestry	1
Development of bioproducts and services	1
Development of new biobased resources	1
Development of scientific and technological innovation	1
Digitalisation	1
Enzyme biotechnology	2
Evaluation and characterization of biomass resources	1
Exhaust gas cleaning	1
Facility design and operation	1
Fate and effects of xenobiotics (elective course)	1
Fiber technology	3
Food processing, quality and new products	15
Forest based products and related processes	4
Functional materials, advanced materials, nanomaterials, biomed materials	9
Genetic engineering	13
High Pressure Fluids and Supercritical Fluids. Applications in the Pharmaceutical Industry, Cosmetic Industry and Agro Food Industry.	1
Hydrology and Water Management (major)	1
Improvement of fish production	1
Industrial Environmental Engineering and Management	4
Introduction to heterogeneous catalysis	1
IoT	1
Laboratory surveillance	1
M.Sc. in Protein Science and Biotechnology	1

Marine biology and limnology	1
Marine bioprospecting and bioactive compounds	1
Marketing management	3
Metagenomics and metatranscriptomics techniques in the characterization of complex microbialsamples and their possible applications	1
Microalgae Biotechnology production and new uses	1
Microbial production of recombinant enzymes and drugs	1
Microbiology	3
Molecular biology and biochemistry	1
Molecular plant breeding and farming	1
Nanochemistry Laboratory	1
Nanomaterial synthesis, techniques and environmental applications	1
Nanoparticle development: inorganic, organic and hybrid	1
NEMS fabrication and system integration (NEMS engineering)	3
Nutrient Cycling and Environmental Management	1
Optimization on all aspects of material production and management, from procurement to its disposal	1
Photochemical initiation of polymerization processes	1
Plant biotechnology	7
Plastic Processing Techniques	1
Pollution-correcting biotechnologies	1
Polymer chemistry and physics	3
Procedures for the creation of technology-based companies	2
Process development	1
Process systems engineering	1
Procurement and preparation of biomass	1
Production development and management	6
Protection of the territory	1
Pulp and paper technology	2
Quality and safety of fish products	6
Recovery of heavy metals in polluted water using microorganisms	2
Renewable raw materials and resources	3
Research and development of new products and processes	1
Service offering in the industrial and environmental fields	1
Silviculture	1

Small molecules and dendrimers: synthesis, properties and utility. Chirality: molecular recognition andbiological activity	1
Soft materials and metallic nanoparticles: synthesis, functionalization and applications	1
Supply Chain Management, Innovation, Sustainability	1
Supported Catalysts	1
Surface and colloid chemistry	1
Sustainability and Environment	22
Synthetic Biology and Metabolic Engineering	1
Technoeconomic assessment	1
The Biomaterials & Tissue engineering	1
The Biomolecular science and technology profile	1
The institutional framework and the process of analysis and decision making in Ecological Economics	1
The Systems biotechnology and bioeconomy	1
Thermal and electrical applications based on biomass (biofuels production and applications)	1
Toxicology and environmental science	1
Transport phenomena	1
Waste treatment	5
Wood Material Development and Modification	2

UNDERGRADUATE:

Agricultural development	6
Analysis, conception , design and optimization for bioprocesses	1
Applied microbiology	1
Basic knowledge about Chemical reactors	1
Biocatalysis	1
Biochemistry	2
Bio-informatics	4
Biology and chemistry	1
Biomass for bioenergy production	3
Bioreactors and specific equipment for bioprocesses	1
Biotechnology	3
Biotransformation of wastes	1
Chemical Engineering (major)	3
Development of the territory	1
Ecological Engineering	3
Electrochemistry	1
Energy engineering	3
Environment and Natural Resources	10

Fermentation technology	1
Food Technology	10
Genetic engineering	6
Hygiene and nutrition	1
ICT tools for environmental management in industry and public administrations	1
Industrial innovation and design	6
Knowledge of molecular mechanisms	1
Knowledge of morphological and functional aspects of the human body	1
Laboratory skills	1
Management of the agricultural, forestry and environmental system	1
Marketing of herbal products	1
Material technology	1
Materials and Surface Engineering (major)	1
Metabolic Engineering	1
Microbial genetics and technology	1
Microbiology	1
Monitoring of processes and installations for manufacturing of pulp, paper, board and other fiber-based products	1
Nanochemical synthesis for new chemical compunds	1
Nanochemistry and nanomaterials	1
New venture development	1
Polymers molecular modeling and simulation to design rheological and processing properties	1
Protection of the territory	1
Quality control of herbal products and nutraceuticals	1
Quality of productions	1
Reduction of environmental impact	1
Start your own business	1
Study and characterization of biofuels types	1
Study of medicinal plants	1
Sustainable Tourism	1
Technical-economic assistance to companies	1
Urban water management and characterization	1

4. By way of conclusion

During the work with education programmes, we have realised how different the educational programmes are both among countries in EU and even within each particular country.

An *example* is the structure of the first and second cycle in the higher education. In Spain, it seems to be 240 ECTS and 4 year for a bachelor's degree, and 60 ECTS and 1 year for a Master. In North Europe the bachelor study is 180 ECTS (or 210 ECTS with in-company training activities), and 120 ECTS for a master.

In Denmark, a master is almost made by elective courses, and the thesis work is 30 – 60 ECTS. This means that you individually can make a master education with a very strong focus on bio-based industry activities (without any notice on the institution's web page). And for a PhD, it is totally individually.

Furthermore, most *engineering programmes* in Denmark are based on the CDIO (Conceiving - Designing - Implementing - Operating) learning principle (http://www.cdio.org/), which are very aligned with the needs of the industry.

In France, for instance, VET *programmes* are offered at a wide range of institutions, from secondary education to higher education following particular professional itineraries.

We are also aware of the fact that bio-industry related courses are growing as non-official, informal adhoc training courses in different technological centres and other institutions that are not commonly education providers. However, the aim of this study was to give account only on official education *where* the lacks need to be identified in order to secure better and more consistent educational answers to bio-industrial needs.

One major conclusion from the database, specifically from the Netherlands part and at MSc level, is that bio-economy is mostly included in broader disciplines and rarely the main title of a degree. Importantly, it can be included in MSc related to chemical engineering, environmental engineering, energy engineering, biology or business…and then the topics taught are quite different under the same course name. We also believe that this trend applies to a certain extent to most countries analysed.

As explained in the first part of this document, access to information on educational programmes in the different countries that are part of the European Union has been a complex process; Firstly, due to the diversity of educational systems and ways of organizing studies; Secondly, because of the linguistic diversity among the different countries. In this regard, it should be noted that at the time of the analysis, many of the countries did not have accessible information in English, particularly at lower education levels. Basically, information in English exists when a programme is designed to attract students also from abroad and at least some part of the education is provided in English. Therefore it is natural that many Master/PhD programmes are explained in English and VET programmes are not. This has been a factor that has conditioned access to educational programmes in a large number of countries within the EU.

If we focus on the general results of the study on educational programmes that tackle Bio-economy at European level, we can see that the contents that are developed the most are those related to Scientific and Technical Activities, Agriculture, Forestry and Fishery, Chemical Industry, Energy and water supply, sewerage and waste management, Manufacturing of food, beverages and tobacco and Human health and social services activities. With regards to the sectors of activity to which they are addressed, the analyses performed allow us to observe that the most prominent are Biotechnology, Agriculture, Food Products, Chemical, Bioenergy, Feed and Pharmaceuticals. We can also observe that the majority of the educational programmes that have been given account of are carried out on-site, with little offer of blended-learning (located mainly at the Master's and PhD levels, and almost no training offer on-line,

which could be explained by the need to make use of specialized training spaces for the development of some specialised subjects. In this sense, focusing our attention on the methodologies used allows us to confirm that in more than 60% of cases, and up to 86% in Undergraduate programmes, the lecture / master class is the most commonly used, followed by Laboratory activities, so this could be a feasible explanation for the practically non-existence of online programmes.

Furthermore, the percentage of the in-company training component during the development of the educational programmes in our sample is higher than 50% in all cases, except for PhD.

According to the sources of information, all sub-competencies are presented at the different formative stages, which suggests that we have to refer to them with different levels of depth. From this point of view, it should be considered, in general terms and for all competences, that:

The levels of depth would refer to basic information (terminology and general laws to be applied in a given competence), technical training (knowledge about theories, processes and their application) and in-depth training (focused on the analysis of processes, the investigation of their causes and the study of conceptual and methodological alternatives).

Surely, the first level of basic information and technical training would be observed at VET and Undergraduate levels, while the in-depth training would correspond to Master (technical training applied to the analysis of reality and innovation processes) and to a Doctorate (more focused on research).

The analysis of the general competences allows for the following conclusions respectively:

- **Management:** sub-competences such as *Quality* and *Product / Logistics* and *Resources* are featured prominently at all educational levels analysed, in addition to *Project Management* at the Master's and Undergraduate levels.

- **Data Management:** in this competence the subcategories of *Data Analytics*, *Advanced Analytics* and *Data Architecture* are present in educational programmes at all levels, with a greater presence of *Data Sensing technologies* and *Data Processing* and *Information Security* at the Undergraduate and VET levels.

- **Personal Initiative and Entrepreneurship:** *Critical thinking*, *Problem Solving* and *Creativity* are considered at all the educational levels, although they have a more intensive presence in PhD.

- **Soft Skills:** the sub-competences linked to communication are the most developed in the different educational programmes in relation to this competence, followed by *Collaboration*. In the case of the VET level, *Personal Branding* also stands out.

- **Sustainability and Industry:** in this case it is not observed that competences are treated with the same intensity at different educational levels. It is the *Sustainable competitiveness economy* sub-competence that is most present in all programmes.

- **Technology:** the results show that, in general terms, this competence is not widely developed in the different educational programmes analysed, being the subcategories of *Key enabling Technologies for bio-based industry* the most present in PhD, *Information and Communication Technology* in the Masters' and Undergraduate, whereas in the case of VET, the most developed is *Traceability and logistics*.

- **Research and Innovation:** the sub-competences that make up this competition are mostly present in the PhD and Master programmes, although the subcategory of *Analytical Capacity* and *Innovation and Change* are also very present at the Undergraduate level.

- **Basic Scientific Knowledge**: the sub-competences linked to this competence are most worked at Undergraduate educational level. *Chemistry*, is the most present sub-competence at all levels except at the VET level, where *Biology* is more present.

- **Rules and Regulations:** the sub-competences of *Quality, safety and security regulations* and *Local legal regulations* are highly represented at each level, while, *Digital compliance* and *Patent regulations* are not.

- **Social Responsibility - CSR**: in this case, different depths of each sub-competence can be seen depending on each educational level. Thus, in the PhD the most present sub-competence is *Ethical responsibilities*, in the case of the Master and Undergraduate it is *Environmental Responsibility* and in the case of VET it is *Green Engineering Awareness*.

- **Sales and Marketing**: in this case the PhD, Master and Undergraduate programmes are similar, especially the sub-competences *Openness of the industrial processes and products* and *Adapting the products to new targets*. In the case of VET, the most present sub-competence is *Adapting the products to new targets*.

The analysis of the specific competences related to the Bio-industry allows us to conclude that:

- **Specialists in Bio-based business / market development sector:** this competence has more presence in the Master and Undergraduate programmes, with *Bio-based market knowledge & techno-economic expertise* the sub-competence most present in these programmes. In the case of PhD and VET, *To raise society's awareness on circular bio-based economy* stands out.

- **Technical expertise in sustainable biomass production**: the presence of the different sub-competences of this competence in the different educational levels is homogeneous, being the one that most often appears related to *Techno-economic assessment of processes, biorefineries and bio-based value chains*.

- **Technical expertise in primary conversion processes:** in general, the sub-competences that make up this competition focus on the Master and PhD levels, followed by Undergraduate, with *Methods for efficient and cost-effective biomass production* being the sub-competence most present at all levels.

- **Technical expertise in secondary conversion processes:** the sub-competences that make up this competence are developed more in the field of Master and Undergraduate, being *Design of Control of systems for robust, stable and sustainable production, quality and contaminants monitoring* the widest developed.

- **Technical expertise in materials, products and functionalization**: in general, the same sub-competences are indicated at all educational levels, the most prominent being those linked to *New chemical building blocks for renewable resources* and *New functional bio-based materials and products*.

The cross-analysis of the results of this report with the one elaborated in the framework of the project related to the competence needs of the industry should allow for the identification of the GAPS present in the educational programmes. This will be the basis for the development of a set of recommendations that should serve to guide a better adaptation of educational programmes to the needs of the Bio-industry sector at European level.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