Specialisation and Cross-disciplinarity Patterns and the Design of New Higher Education Programmes

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ABSTRACT

In the last decade, Spanish universities have been reforming their teaching programmes on the basis of a set of common guidelines. Such guidelines determine 50% of the academic courses to be studied in the different programmes. They also assign each academic subject to one or several of the areas of scientific specialisation that the universities use to classify their teachers. The aim of the present work is to analyse the different ways that academic courses are distributed by scientific areas in terms of specialisation and cross-disciplinarity levels. The results are relevant for the efficient allocation of human resources and in the estimation of the costs involved in curricular reform.

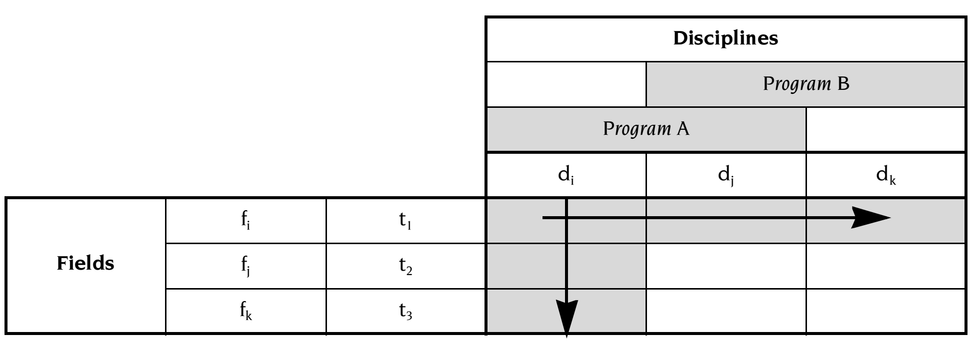
INTRODUCTION

The starting point of this paper is the common idea that natural sciences are more specialised than social sciences and humanities (Braxton, 1996; Colbeck, 1998). These different levels of specialisation have many implications for the organisation of higher education programmes: from *curriculum* to human resources policy implications. We have had a look at Spanish University programmes to see if we can assume this hypothesis and to what extend this prejudices are present.

First, in this work, we make the distinction between *scientific fields* or *area* and *scientific disciplines*. A given researcher will consider himself to be a specialist in a particular scientific field but in order to work in that area he needs to master and to be able to use methods and results coming from several different disciplines. Specialists from other fields also use many such disciplines (sometimes all of them). One can therefore divide the whole set of scientific disciplines mastered by a specialist in a given scientific field into two classes: disciplines whose mastery and use he shares with specialists from other fields, and disciplines that only he has mastered and uses. For instance, S*tatistics* is a scientific discipline whose contents are shared with many scientific fields (Applied Mathematics, Research Methods, etc.).

This characteristic of the competencies of scientific specialists is of particular relevance in the organisation of higher education. A university programme aims at providing scientific, humanistic or technological training in a given scientific or professional area. The training of an undergraduate in any given field (Law, Economy, Physics, Electrical Engineering, etc.) requires that person to become adept in several scientific disciplines. Each of these in turn requires the participation of a specialist teacher. Thus, in view of the complex structure of scientific specialisation, the following situations can be entertained:

– A specialist teacher (t_1) in a field f_i may be competent to teach several disciplines $d_i \ldots d_n$.
– A discipline d_i can be taught by teachers ($t_1..t_3$) who are specialists in different fields $f_i \ldots f_n$.



In general, for an efficient allocation of human resources in higher education, two situations can be thought to be desirable:

1. The availability of teachers whose scientific specialisation allows them to master different disciplines.
2. The organisation of studies (programmes) comprising disciplines that can be taught by teachers having different specialities.

However, it would appear that powerful undercurrents act to hinder the emergence of such situations; currents that force scientific specialists to concentrate their efforts in disciplines exclusive to each area and that also force a monolithic design of also highly specialised graduate training programmes. These trends towards specialisation can be justified in terms of reasons inherent to the dynamics of science itself. A much cited example is the success achieved by the experimental sciences, which is due precisely to the concentration of efforts that specialisation has permitted, *versus* the humanities disciplines, apparently condemned to generalisation and a relative stagnation.

It would thus appear that the requirements of efficiency for the allocation of human resources in higher education are in contradiction with the demands deriving from the internal structure itself of science such that those principles of efficiency can only be applied in social science and humanities programmes but not in scientific and technological disciplines.

Our aim here is to offer empirical evidence in support of serious doubts about the pertinence of these prejudices concerning scientific specialisation. Our data, derived from the disciplinary organisation of the Spanish University system, point to a structure that to a certain extent can be considered the opposite of what would be expected. I*t is in the humanities and social sciences – not in the experimental sciences or technologies – where the strongest trend towards specialisation and isolation emerges.*

DATA

The 54 Spanish universities impart some 134 training programmes that are recognised as official by the State. Each university has the freedom to organise its programmes as best it deems although certain legal requisites must be observed if the degree courses imparted are to benefit from State recognition. These requisites refer to the duration, structure and contents of the programmes. For example, with respect to duration current legislation establishes two types of university programme depending on whether it leads to a Diploma, a technical degree in Engineering or a technical degree in architecture (the minimum duration for these is three years) or whether it leads to a full degree as a licentiate or a full degree in engineering or a full degree in architecture (minimum duration 4 or 5 years except in the case of medicine, where it is 6 years).

Regarding structure, programmes must meet certain requirements *vis à vis* the type of subjects involved (obligatory or elective), the type of teaching (theoretical, practical, etc.) and the "credit load" (unit of measurement convertible into class hours: in general one credit is equal to 10 hours of academic activity). Finally, as regards contents, the law stipulates a series of "core" subjects which must necessarily be imparted in each programme or degree for it to be recognised by the State. The directives that specify these core subjects also indicate the number of credits each of them "is worth" and offer a brief description of their subject content. Generally, the number of credits assigned to these core subjects ranges between 40% and 60% of the total amount of credits of each program, although in technical degrees these limits are upgraded. For the whole set of 134 official degrees that students can opt for in Spain, the directives of each degree establish a total of 1 048 different core subjects.

Another characteristic of the Spanish university system is that tenured lecturers, who are all civil servants, are classified within what are known as "areas of knowledge": that is in scientific fields depending on their own specialisation. Currently, the complete coverage of Spanish university encompasses 174 scientific areas, ranging from humanities disciplines to scientific and technological specialities. It must be pointed out that this classification has no level, so that these 174 "areas of knowledge" are independent.

The directives that stipulate the core materials of each programme also specify the requisite scientific specialities that allow teachers to impart those core materials.

We have used this catalogue of core materials and areas of knowledge to analyse the disciplinary structure of higher education in Spain. The data scrutinised only cover about half of the effective programmes taught in the universities but we consider this part to be significant in the sense that it is precisely the part that all universities must respect if their degrees are to be recognised by the State. Although no definitive data are available, one can readily assume that the complete structure of the programmes to a large extent reproduces the structure imposed by current legislation as regards core subjects. In fact when conflict arises in university departments concerning teaching programmes it is a common practice to apply criteria analogous to those relating to government-imposed core materials.

Tables 1 and 2 depict the most relevant overall data. There are 134 official degree courses available in Spanish universities. Overall, official directives specify 1 048 different core subjects for these 134 degrees. Lecturers are classified into 174 areas of knowledge. In most cases (69%) any given core subject, belonging to one or several programmes, can be taught by lecturers *from more than one area of knowledge*.

Table 1. **Description of programmes**

Branches	A	B	C[1]	D	E	F (%)	G (%)	H
Humanities	26	201	1.61	1.10	133	42	66	783
Experimental and natural sciences	12	126	4.44	3.01	22	7	17	1 489
Social sciences and law	28	237	2.30	1.37	84	26	35	881
Technologies	60	381	3.24	1.99	47	15	12	1 625
Health sciences	8	103	2.91	2.16	34	11	33	364
Total	**134**	**1 048**	**2.83**	**2.08**	**320**	**100**	**31**	**5 146**

1. Significant differences, $p < 0.01$.
A = Number of different programmes.
B = Different courses per KA.
C = Mean of different KA per course.
D = Standard deviation (C).
E = Courses assigned to only one KA.
F = Percentage of column (E).
G = Percentage E/B.
H = Number of assignations to areas.
Source: Authors, based on data from the Spanish Council of Universities.

Table 2. **Course per cycle**

Cycle	B	C[1]	D
First	579	2.81	2.08
Second	469	2.85	2.09
Total	**1 048**	**2.83**	**2.08**

1. No significant differences, $p = 0.78$.
Source: Authors, based on data from the Spanish Council of Universities.

METHOD OF ANALYSIS

Using the data available, we compiled the profile of each scientific area on the basis of three characteristics:

1. **Its inclusion within one of the five branches**, or major areas of knowledge, traditionally seen in Spanish universities (Humanities, Social sciences and Law, Mathematical and Natural Sciences, the Health Sciences and Engineering).

2. **Its polyvalence**: *i.e.* the number of different core materials that can be taught by lecturers who are specialists in that area.

3. **Its exclusivity:** the percentage of core materials that can be imparted exclusively by lecturers belonging to the area with respect to the overall core materials that *those same lecturers* can teach.

The **classification into branches** was done *in a purely conventional way* following the practices established by the Spanish universities and the Spanish University Council. This classification is in general use in official programmes and is an extension of the former classification into “Schools” or “Faculties”. Its application to areas of knowledge can be accomplished either as a function of the branch in which each area of knowledge has the most “competencies” (more core subjects assigned) or using other, also conventional, criteria linked to academic tradition (for example the area of Mathematical Analysis has traditionally been assigned to Faculties of Science although it has more core subjects in degrees pertaining to the branch of Engineering). Although in this a certain degree of randomness is inevitable, this does not invalidate the results obtained.

Polyvalence in an area of knowledge is measured *by the total number of assignations of core subjects that the area receives in the directives relating to official degrees*. As specified in Table 1 (H), there are 5 146 assignations to 174 areas, giving an average of 29.5 assignation per area. In fact, this magnitude includes two data items that may refer to different properties: one area of knowledge may have a polyvalence value of n either because it has been assigned n different core subjects in a single degree (or in degrees from a single branch) or because it has been assigned a single core subject that is repeated with the same name in n degrees of one or several branches, etc. Although the different possibilities certainly respond to significantly different disciplinary situations, for the issues addressed here they can be considered to be equivalent: teachers from an area of knowledge with polyvalence n can cover n possibilities of teaching in core subjects in university programmes either because the (few) subjects they master in their speciality are of very general interest for many different programmes or because their speciality allows them to master many different teaching subjects.

The **exclusivity of an area of knowledge** was measured by the percentage of core materials assigned exclusively to that area with respect to the total amount of core materials assigned to it. This may be understood as a measure of the irreplaceable nature of specialists in each area of knowledge. Indeed, if a core subject is assigned exclusively to one area of knowledge, this means that in order to be able to impart the programme(s) that include that subject the university must have teachers who are specialists in that area. Reciprocally, if one area of knowledge is not exclusively assigned any core subjects then this means that the university will be able to organise any kind of programme without having to have specialists in that area. In the case examined, the range of this magnitude is between 0% and 100%; in particular there are 56 areas that do not have any exclusively assigned core subjects and only 6 areas for which more than 50% of the subjects assigned are exclusive to those areas.

Polyvalence and exclusivity can be considered to be relatively independent properties. Within certain limits, an area of knowledge may be highly polyvalent but not very exclusive and *vice versa*.

To analyse the differences in polyvalence and exclusivity among the areas of knowledge of the five major branches, we replaced the direct measurements of polyvalence and exclusivity by their normalised scores (their differences with respect to the mean, in units of standard deviation). This allowed us to group the areas of knowledge in four groups corresponding to the four quadrants depicted in Figure 1, depending on whether their respective scores on polyvalence and exclusivity are positive or negative. The asymmetric distribution of both variables is reflected by the fact that approximately 2/3 of the areas of knowledge have a polyvalence lower than the mean while another 2/3 also have an exclusivity value lower than the mean.

The areas of **Group I** are those showing both polyvalence and exclusivity above the mean. They are therefore areas that have competence in more core subjects than the mean of the areas and for which the percentage of subjects assigned exclusively to them is also above the mean.

The areas of **Group II** are those displaying high polyvalence and low exclusivity. They are therefore areas fulfilling the desideratum of the university manager: lecturers who are specialists in these areas are good at doing many things and are readily interchangeable.

The areas of **Group III** are less polyvalent than the mean but also less exclusive than the mean. This is the most numerous group in the Spanish university system (37% of the total number of areas of knowledge).

Finally, the areas of **Group IV** are the nightmare of any university management team: specialists in these areas only teach a very few core materials and, furthermore, cannot be substituted by others. The implementation of programmes in which this type of lecturer is required may lead, in the absence of a suitable scale dimension, to the typical situation of underexploited teaching capacity.

RESULTS

The different types of behaviour of the several large areas or branches into which areas of knowledge can be divided are significant. In particular, as may be seen in Tables 3 and 4, the areas of both experimental and technological sciences are characterised by low exclusivity (more than 90% of the areas have an exclusivity lower than the mean) and a high degree of polyvalence (more than 60% of these areas have a polyvalence higher than the mean). In contrast, humanities have an inverse pattern: high exclusivity (70% higher than the mean) and low polyvalence (70% lower than the mean). The health sciences are characterised by low exclusivity

Table 3. **Number of areas of knowledge per scientific branch and group**

Branch	Group				
	I	II	III	IV	Total
Experimental sciences	2	18	12	0	32
Humanities	13	0	13	17	43
Heath sciences	0	0	18	6	24
Social sciences and law	4	6	14	15	39
Technologies	0	25	8	3	36
Total	**19**	**49**	**65**	**41**	**174**
	Group (Percentage)				
	I	II	III	IV	Total
Experimental sciences	6	56	38	0	100
Humanities	30	0	30	40	100
Heath sciences	0	0	75	25	100
Social sciences and law	10	15	36	38	100
Technologies	0	69	22	8	100
Total	**11**	**28**	**37**	**24**	**100**
	Group (Percentage)				
	I	II	III	IV	Total
Experimental sciences	11	37	18	0	18
Humanities	68	0	20	41	25
Heath sciences	0	0	28	15	14
Social sciences and law	21	12	22	37	22
Technologies	0	51	12	7	21
Total	**100**	**100**	**100**	**100**	**100**

Source: Authors, based on data from the Spanish Council of Universities.

and low polyvalence. The social sciences and law show low polyvalence and a fairly balanced situation as regards exclusivity.

It is also possible to characterise the four groups by the type of area of knowledge prevailing in each. Group I is the least numerous (11% of the total of areas) and 68% of all the areas in it belong to the field of the humanities. These, together with the social sciences and law, represent 89% of the total in group I. By contrast, in group II, 51% are technological areas and together with the exact and natural sciences cover 88%. Group III is the most numerous (37%) and also the one in which the areas of knowledge of all the branches are the most homogeneously distributed. Finally, group IV also features a predominance of the area of humanities and social sciences. The humanities cover 41% of the total and, together with the social sciences and law, represent 78% of the group total.

Table 4. **Distribution of areas of knowledge**

Exclusivity	Polyvalence	
	–	+
+	IV	I
–	III	II

Experimental sciences

Exclusivity	Polyvalence (Percentage)		
	Low	High	Total
High	0	6	6
Low	38	56	94
Total	**38**	**63**	**100**

Humanities

Exclusivity	Polyvalence (Percentage)		
	Low	High	Total
High	40	30	70
Low	30	0	30
Total	**70**	**30**	**100**

Health sciences

Exclusivity	Polyvalence (Percentage)		
	Low	High	Total
High	25	0	25
Low	75	0	75
Total	**100**	**0**	**100**

Social sciences and law

Exclusivity	Polyvalence (Percentage)		
	Low	High	Total
High	38	10	49
Low	36	15	51
Total	**74**	**26**	**100**

Technologies

Exclusivity	Polyvalence (Percentage)		
	Low	High	Total
High	8	0	8
Low	22	69	92
Total	**31**	**69**	**100**

Table 4. **Distribution of areas of knowledge** (*cont.*)

All fields			
Exclusivity	Polyvalence (Percentage)		
	Low	High	Total
High	24	11	34
Low	37	28	66
Total	**61**	**39**	**100**

Source: Authors, based on data from the Spanish Council of Universities.

CONCLUSIONS

It is possible to draw some interesting conclusions from the foregoing considerations, both as regards the understanding of certain striking aspects of the disciplinary organisation of knowledge and the organisation of teaching in the Spanish universities.

First, the need emerges to revise the most usual clichés concerning the specialisation that is assumed to be characteristic of the experimental sciences as compared with the globalising nature of humanities disciplines. In view of the data analysed, it would appear that in the Spanish university system the "virus" of hyper specialisation affects the areas of the humanities and social sciences much more than experimental sciences and engineering. It would be interesting to analyse the origins of this situation and its existence in other higher education systems (Huisman, 1995 and 1997). This phenomenon could be crucial for the development of these disciplines, the planning of higher education and the design of new curricula (Jones, 1991).

Some of these consequences seem evident with respect to the organisation of university studies. Traditionally, university teaching costs have been assumed to increase with the increase in the degree of experimental or technological complexity of the programme: it is more expensive to train a physicist than a mathematician and more expensive to train an engineer or doctor than to train a physicist. In any case, humanities degrees have always been considered to be "cheaper" than scientific or technological degrees. Two factors may alter this traditional idea: student numbers and the functional flexibility of the teaching staff. According to studies carried out by some Spanish universities, the combined effect of student scarcity and staff resource inflexibility means that the most "expensive" degrees, per student, are to be found in the humanities. As a hypothesis, one could envisage a situation where making the humanities and social sciences teaching staff more flexible could help to reduce such costs, not only as a result of greater efficiency in the allocation of human resources, which that flexibility would enable, but also due to the greater attractiveness to students of programmes that would be truly generalist in these branches of knowledge, at least as general as most of the programmes of the experimental sciences and traditional technological degrees.

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