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Revising a Geodesy and Cartography Engineering Curriculum*

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In the 1990s, a new degree, Geodesic and Cartographic Engineering, was created in Spain. It is a post-graduate degree, lasting two years. At present, Spanish university degrees are being redefined for their adaptation to the European Higher Education Area (EHEA). Thus, after more than ten years of experience and in view of the implementation of the EHEA, it is essential to analyse how well the degree curriculum is adapted to the professional requirements of our graduates in their working lives. A survey of former students was taken to gather a profile of graduates, job positions and their opinions about the courses they studied. The relationship between the curriculum and the Master's theses written by the students was also examined.

Keywords: Engineering surveying; geodesy; cartography; photogrammetry; mapping; remote sensing; cadastre; curriculum

INTRODUCTION

THE INTEREST OF HUMAN BEINGS in the world around them is ancient; many studies on the shape and size of the planet have resulted from this interest. Land representation has also been important for travel, city planning and military uses.

Worldwide a great variety of programmes exist on every aspect of geospatial sciences: cadastral studies, land administration and surveying, geodesy and satellite positioning, Geographic Information Systems (GIS), web mapping and geoinformatics, imagery systems like remote sensing and digital photogrammetry, cartography and hydrology, geospatial data quality and integration, and so forth. Although before 1990 these courses were organized as Bachelor's degree studies, the development of the geospatial sciences and technologies and the evolution of the society's needs and perceptions regarding geospatial information led to the creation of Master's degrees and PhD programmes. The trend now is to rename geodetic and cartographic engineering as 'geomatic engineering', especially in countries such as Canada, the United States and Australia. A look at the (geo+matic) topics covered suggests this change of name is necessary to emphasize the contribution of computer technology.

The need for a change in these subjects means that universities worldwide have remodelled their programmes, [1] [2] [3] [4] [5] [6] [7] or they are considering doing so at present. In some countries, this process has been a consequence of adapting curricula to the requirements of the different accreditation boards, as in Canada [8] and the United States [9].

In Canada [8], the process of curricular renovation since the 1960s has led to the reduction of hours and courses needed to obtain the degree, going from five years and 225 credit hours in 1965 to four years in 2005 and, more recently, to 160 credit hours. Additionally a huge change in subject content has taken place, with an increase in subjects related to geomatics, land administration, GIS, remote sensing and hydrology, and a diminution in subjects related to photogrammetry and cartographic production.

In Denmark [10], over the last forty years, the professional activity of graduates has changed from concentrating fundamentally on cadastral management to having more to do with cartographic or surveying planning and management, or to activities that, traditionally, have been unrelated to this profession.

IMPLEMENTING THE 'BOLOGNA' PROCESS

Revising and updating degree programme content is particularly important in Europe, where the 'European Higher Education Area' (Bologna

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Process) [11] will implement a European-wide system of comparable degrees to increase student mobility. Today the Bologna process is the principal stimulus for the revision of university degrees. Thus, in countries like Croatia [12] [13], Czech Republic [14], Finland [15], Hungary [16], Ireland [17], Latvia [18], Poland [19] and Slovakia [20] [21], the degrees related to surveying, geodesy and cartography are being redefined. In Finland, Sweden and Denmark, an initiative to establish a collaborative international Master's programme among a grouping of universities has emerged [22].

Teaching in disciplines related to cartography and geodesy must focus on the acquisition by students of management skills (interpretation and maintenance of the information). It must be based on projects and not on subjects, employ the latest educational and technical methods, and serve the continuous learning needs of graduates throughout their whole professional lives [23] [24].

In Spain, cartography and geodesy became important in the fifteenth and sixteenth centuries because of the discovery of America and the colonization of new territories. In the eighteenth and nineteenth centuries, official regulation of these professions began with the creation of the Corps of Cosmographer Engineers and the Military Corps of Geographic Engineers [25]. During the nineteenth century the National Geographic Institute was created, to elaborate the National Geodesic Network and the National Topographic Map. In the middle of the twentieth century, the Bachelor's degree in Surveying Engineering was created, and, in the 1990s, the Master's degree in Geodesic and Cartographic Engineering.

At present, there are six Spanish universities offering a postgraduate degree programme in Geodesy and Cartography. The curriculum is different at each university, but all require at least 870 classroom hours in total, distributed among Photogrammetry, Geodesy, Geophysics, Applied Computer Science, Applied Geography, Mathematical Methods and Cartographic Systems and Processes [26].

As in other European countries, in Spain the process of redefinition of university degrees for their adaptation to the European Higher Education Area (EHEA) has begun. Until now, the only information known about the new academic model is that it will be comprised of an under-graduate degree of four years and a minimum of 240 credits and a postgraduate degree of one or two years (60 or 120 credits). After more than ten years offering this new Master's degree (Geodesic and Cartographic Engineering), and considering the requirements of the EHEA, a time for review is necessary. For this purpose, a research project has been carried out to analyze how well the curriculum is adapted to the requirements of graduates' future job. A survey of former students was taken to ascertain their characteristics (degrees, ages, gender, etc), their jobs, and their opinions about the courses in the curriculum. The relationship among courses, students' Master's theses, and job positions has also been studied.

CURRICULUM AND MASTER'S THESIS

The admission requirements to Geodesic and Cartographic Engineering postgraduate degree are a Bachelor's degree in Surveying or a Bachelor's degree in Geography; in the last case, the students must complete between 21 and 27 credits distributed among Geology, Physics and Mathematics (1 credit = 10 classroom hours) [27].

Table 1 shows the subjects for the Geodesic and Cartographic Engineering Curriculum at the Technical University of Madrid (UPM) and the number of credits assigned to each of them [28].

When Spanish university degrees are adapted to the EHEA, ECTS (European Credit Transfer and Accumulation System) credits will be used. But until then, the number of classroom hours (1 credit = 10 classroom hours) will be used as an indication of a subject's importance. The Master's degree comprises two academic years. Most of the subjects are compulsory and deal with Photogrammetry, Geodesy, Geophysics, Applied Geography,

Table 1. Subjects of the Geodesic and Cartographic Engineering Curriculum at the Technical University of Madrid

Subjects of the First Year	Character	Credits
Advanced Mathematics	Obligatory	7.5
Advanced Computer Science	Obligatory	3
Analytic Photogrammetry	Obligatory	9
Databases	Obligatory	3
Geophysics	Obligatory	4.5
Applied Geography	Obligatory	3
Non-Cartographic Photogrammetry	Obligatory	3
Mathematical Cartography	Obligatory	3
Advanced Geodesy	Obligatory	6
Advanced Physics	Obligatory	4.5
Geostatistics	Obligatory	3
Adjustment Computations	Obligatory	4.5
Remote Sensing	Obligatory	6
Geomorphology	Optional	3
Metrology	Optional	3
Structural Analysis	Optional	3
GPS Technologies	Optional	3
Subjects of the Second Year	**Character**	**Credits**
Digital Photogrammetry	Obligatory	6
Physic Geodesy	Obligatory	6
Land Planning	Obligatory	9
Geographic Information Systems (GIS)	Obligatory	6
Thematic Cartography	Obligatory	4.5
Cartographic Production	Obligatory	4.5
Cadastre and Land Information Systems	Obligatory	6
Engineering Projects	Obligatory	6
Computer Graphics	Obligatory	3
Displacement Measurements	Obligatory	4.5
Economy and Business Administration	Obligatory	3
Master Thesis	Obligatory	4.5
Hydrology	Optional	3
Numerical Methods	Optional	4.5
Earthquake Engineering	Optional	3
Infrastructures	Optional	4.5

Applied Computer Science, Mathematical Methods and Cartographic Systems and Processes. The students can freely choose optional subjects that account for 16 per cent of their first year credits and 20 per cent of their second year credits.

As part of their work, students must complete a thesis. Students are free to choose the field of their thesis. For this reason, the analysis of the topics chosen for theses completed is considered a source of information about the thematic preferences of the students and the skills they consider useful in their post-graduation job search.

To carry out this analysis subjects have been grouped in thematic areas. Subjects that develop similar or related skills have been grouped in the same thematic area. For example, the subjects of Mathematical Cartography, Thematic Cartography and Cartographic Production have been grouped in Cartography. In the same way, the subjects of Analytic Photogrammetry, Non-Cartographic Photogrammetry and Digital Photogrammetry have been grouped in Photogrammetry. The thematic area Geodesy includes the subjects Advanced Geodesy and GPS Technologies. The subjects Advanced Computer Science and Computational Graphics have been grouped in the thematic area Computer Science. The GIS thematic area includes the subjects Cadastre, Databases and GIS.

Table 2 shows the thematic areas and their credits. The thematic area with the highest number of credits is Photogrammetry (18 credits), which represents 12 per cent of the entire degree program. GIS with 15 credits (10 per cent) is in second place, followed by Cartography with 12 credits (eight per cent) in third place. Geodesy and Land Planning have nine credits assigned (six per cent) to each.

All Master's theses—117 of them—completed by students since the inception of the degree programme in the UPM have been analyzed. More than half of them are from four thematic areas: GIS (16 per cent), Infrastructures, (15 per cent), Cartography (15 per cent) and Geodesy (10 per cent).

Table 2. Thematic areas established and credits

Area	Credits
Cartography	12
Displacement Measurements	4.5
Structures	3
Photogrammetry	18
Geodesy	9
Physical Geodesy	6
Geophysics	4.5
Hydrology	3
Computer Science	6
Infrastructures	4.5
Metrology	3
Land Planning	9
Geographic Information Systems (GIS)	15
Remote Sensing	6

Figures 1 and 2 show, respectively, the percentage of theses by thematic area, and a comparison, for each thematic area, between its percentage of theses and its percentage of credits in the curriculum. GIS is the thematic area for which the most theses have been written, 19 theses (more than 16 per cent of the total). This area is the second most important in the curriculum (10 per cent of the whole degree credits). Given students' interest in skills related to GIS more credits could be assigned to this topic.

Infrastructures is the second highest thematic area in number of theses written, with a total of 18 theses (a little more than 15 per cent of the total). This area has only 4.5 credits, which accounts for three per cent of the total number of credits in the curriculum. So it seems reasonable to increase the number of credits of this area. Furthermore, as it is an optional subject, only those students interested in this area choose it.

Next, is the area of Cartography, with a total of 17

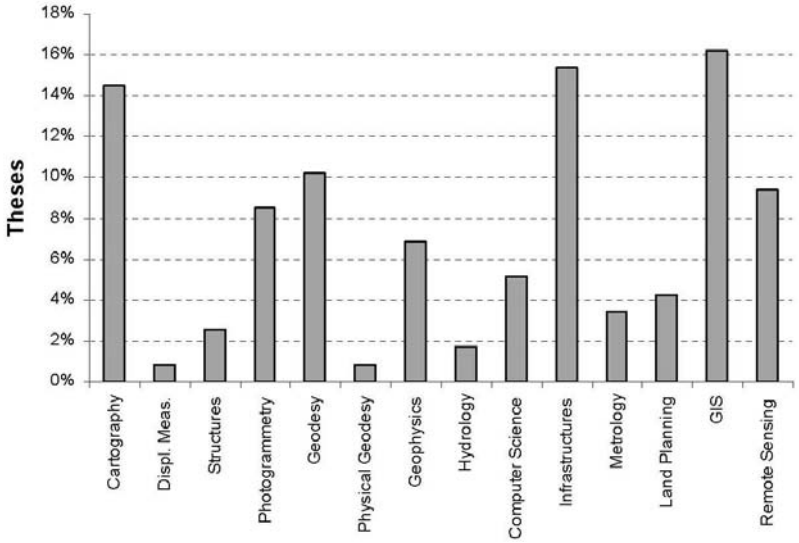

Fig. 1. Master's theses percentage by thematic area.

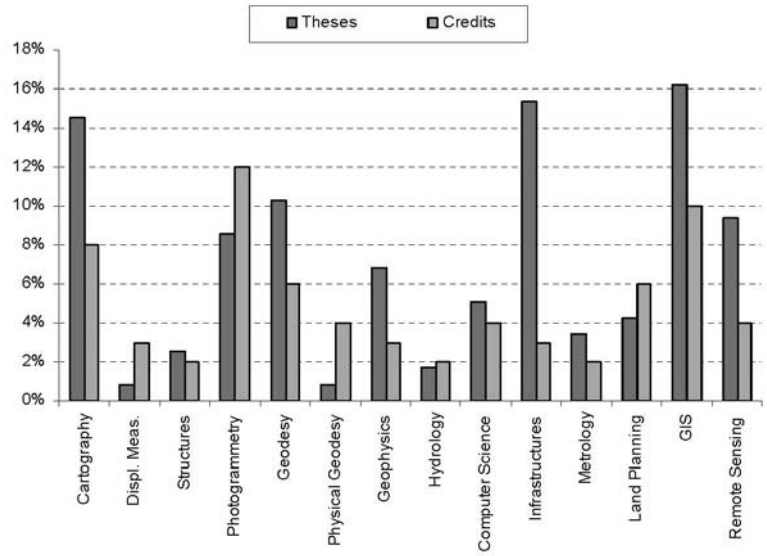

Fig. 2. Comparison theses % and credits %.

theses, which represents more than 14 per cent of the total, and whose 12 assigned credits represent eight per cent of the total credits of the curriculum.

The areas of Geodesy, Remote Sensing, and Photogrammetry are next with 12 (approximately 10 per cent), 11 (more than nine per cent), and 10 (less than nine per cent) theses, respectively. These areas have a high number of credits: Photogrammetry has 18 credits (more than 12 per cent of the total). Photogrammetry is the area with the highest number of credits in the curriculum, which seems excessive. Physical Geodesy also has a high number of credits in relation to the number of theses finished. Displacement Measurements and Physical Geodesy are the subjects about which the fewest theses have been written.

In general, except for the previously indicated exceptions, the curriculum seems well adapted to the professional needs of the students, analyzed through their thematic interests shown in their Master's theses.

GEODESIC AND CARTOGRAPHIC ENGINEER (GCE)

A survey of former students has been taken to ascertain their profile, their jobs, and their opinion about possible modifications to subjects in the curriculum. The survey was carried out in May 2007. All graduates, from the beginning of the programme to the ones graduated in February 2007 were contacted. The survey involved 120 persons, 81 men and 39 women. They were contacted by phone, e-mail and ordinary mail. The survey form was sent by e-mail and by ordinary mail. 25 per cent answered the questionnaire (17 men and 13 women). These answers were received by ordinary mail and by e-mail, mainly the latter. There is a copy of the questionnaire in the appendix.

Among the graduates, men are in the majority (68 per cent to 32 per cent). However, there are fewer women at a Batchelor's level at only 26 per cent. [29]

The professional stability of the graduates is quite high, as 43 per cent are civil servants, and 33 per cent have permanent positions, as opposed to 10 per cent who are working on a contract basis. Of graduates, seven per cent have internships, and seven per cent have temporary or part-time jobs.

At present, 57 per cent of graduates work for companies with more than 500 employees. This could be due to the high number of graduates who have become civil servants.

The employment rate of the graduates is very high, since all of them have jobs; 80 per cent are contracted as GCEs and 10 per cent as surveyors. The remaining 10 per cent hold jobs not related to the field. These data indicate that the graduates have the skills suitable for the job market.

Geodesic and Cartographic Engineers mainly occupy positions of management and coordination, 40 per cent as Senior Engineer, and 33 per cent as Group or Project Leaders.

Graduates' placement in the job market is quite rapid, since 57 per cent have their first job as a GCE within the first year after graduation, and 70 per cent, within two years. Because of this rapid placement, half of the graduates have professional experience in excess of three years.

Figure 3 shows the main work areas of the graduates. GIS and Cartography are the most frequent with 18 per cent and 17 per cent, respectively, followed by Geodesy and Land Planning with 13 per cent and 11 per cent. Photogrammetry with 10 per cent and Remote Sensing and Computer Science with nine per cent follow. Only seven per cent of graduates work in surveying.

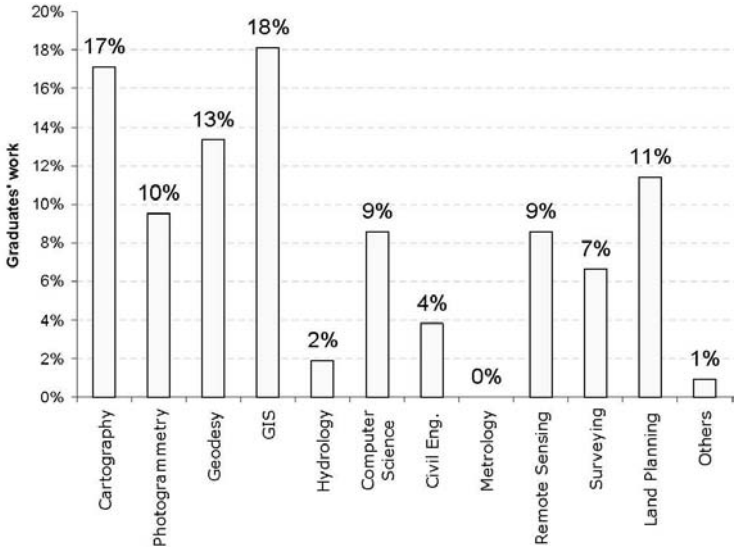

Fig. 3. Work done by graduates.

As mentioned previously, the degree of Geodesic and Cartographic Engineering is a Master's, to which a Bachelor's degree in Surveying Engineering provides direct access. Geographers can also be admitted to these studies by means of a test, and after the completion of some additional subjects. According to the survey, 43 per cent of graduates chose the GCE profession because they liked it, and 17 per cent to improve their career prospects. Results indicate that 87 per cent of Geodesic and Cartographic Engineers have improved their job conditions by pursuing these studies. In general, graduates consider that the skills taught are well adapted to cover their professional needs, although practical experiences were lacking from the programme. In particular:

- 32 per cent of graduates consider that the credits in Advanced Geodesy should be increased, as opposed to 50 per cent who think they should remain the same;
- 30 per cent of graduates consider that the credits in Digital Photogrammetry should be increased, and 37 per cent would leave them unchanged;
- 23 per cent of graduates consider that the credits in Structural Analysis should be reduced while 63 per cent think they should remain as they are now;
- 21 per cent believe that Applied Geography should be eliminated from the curriculum, as opposed to 61 per cent who think it should remain as it is;
- all graduates consider that the number of credits of the remaining subjects should not be changed.

Although Geodesic and Cartographic Engineers occupy positions of management and coordination mainly, the surveyed graduates think that the hours dedicated to these topics in the subject Engineering Projects do not need to be increased.

Finally, the surveyed graduates consider that subjects in Web development, Microgeodesy and foreign languages must be added to the curriculum.

ANALYSIS OF RESULTS

The survey revealed the main areas in which graduates are working (Figure 3 above). To know if the education received is well-suited to the needs of industry, the results have been compared with the curriculum of the degree. For the sake of simplicity, the list of work areas came from the previous classification of thematic areas found in the curriculum. Thus, the subjects Geodesy and GPS Technologies correspond to the Geodesy work area. Infrastructures corresponds to Civil Engineering. The subject Land Planning is associated with the Environment and Land Planning work areas.

Figure 4 allows comparison of the present work areas of the graduates and the corresponding assigned credits in the curriculum. In this figure, the work areas that have no corresponding areas in the curriculum have not been considered, and as a result the percentages could vary from percentages in Figure 3 above. The graduates' main area of professional activity is GIS, which accounts for almost 19 per cent of the graduates but only 10 per cent of the curriculum credits. This large difference seems to suggest there are not enough credits in GIS. The next most important work area is Cartography, accounting for more than 18 per cent of graduates' activity, and only eight per cent of the credits in the curriculum. This difference suggests that increasing its assigned credits would be advisable, due to the importance of skills in this area for graduates. The situation with Geodesy is similar. It is the third most important work area with 14 per cent of the graduates and only six per cent of curriculum credits. Something similar occurs

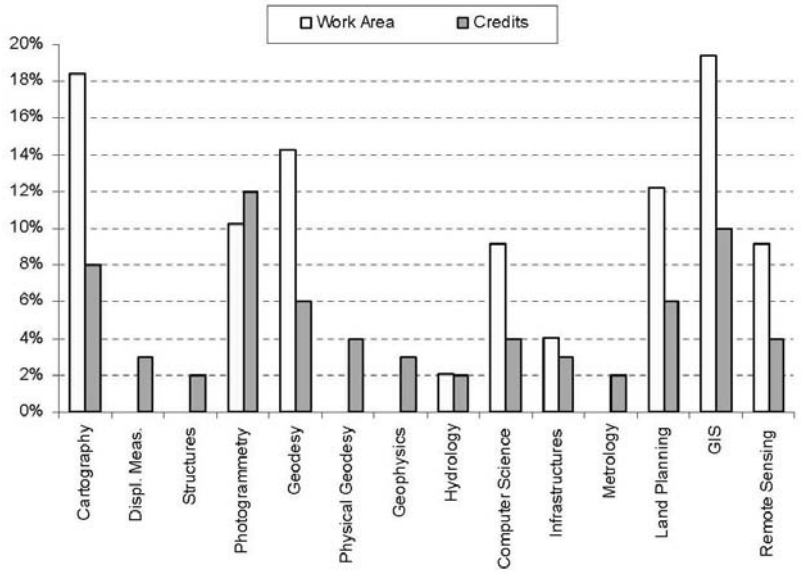

Fig. 4. Comparison credits %, theses % and work area %.

with other areas like Planning, Remote Sensing and Computer Science. The opposite occurs with Photogrammetry, the fifth most important work area. With only 10 per cent of graduates, Photogrammetry has the highest percentage of curriculum credits, 12 per cent of the degree.

It must be remembered, however, that Geodesic and Cartographic Engineering graduates do not work in areas like Geophysics and Metrology, but such knowledge is considered necessary to the development of essential skills for these GCEs. Graduates in Geodesic and Cartographic Engineering do not work in the Structures and Displacements Measurements areas either, and as these subjects are not especially important for GCEs, a reduction of their curriculum credits should be considered.

The relationship among area credits, the number of Master's theses written and the importance for graduates' employment has also been analyzed (Figures 5 and 6). In the graduates' main work area, Cartography, the percentage working in this field is similar to that of Master's theses completed. Nevertheless, the comparison between both ratios (%thesis/%credits and %work area/%credits) suggests that the curriculum credits of the area should be increased in response to graduates' needs.

In the GIS area, the number of Master's theses closely reflects the importance of the field in terms of the percentage of graduates working in it. However, the assigned credits do not seem to be enough, given the high demand in this area. Thus, increasing GIS curriculum credits is perhaps advisable.

A very high percentage of Master's theses are written on the subject of Infrastructures. Nevertheless, the number of graduates working in this

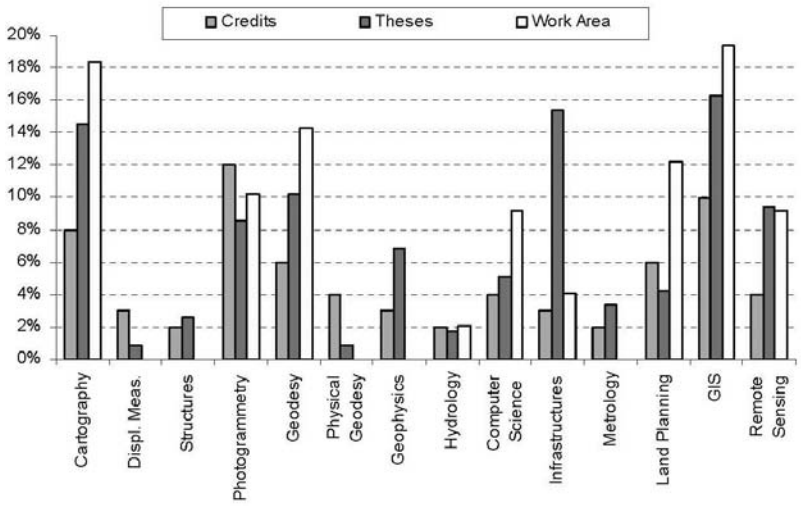

Fig. 5. Comparison credits %, theses % and work area %.

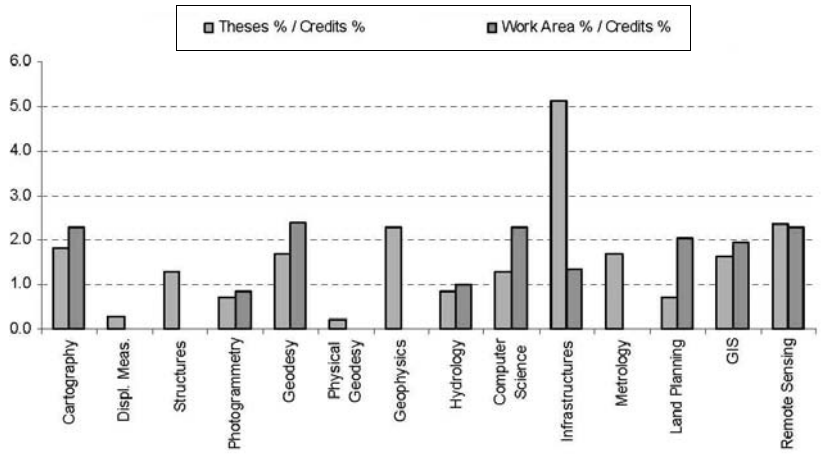

Fig. 6. Comparison credits %, theses % and work area % ratios.

area is low, only three per cent, so increasing its curriculum credits does not seem necessary.

Many Master's theses are also written on the topic of Remote Sensing, and a great many graduates work in this field. However, as the number of curriculum credits in Remote Sensing is low, an increase could be considered.

Photogrammetry is the area with the highest number of credits in the curriculum, and although the number of Master's theses and of graduates working in this area is high, the number of curriculum credits seems excessive. Perhaps it would be advisable to reduce the number of these credits.

The Displacement Measurements and Structures areas do not constitute a work area for Geodesic and Cartographic Engineering graduates. The number of Master's theses written has been low and these topics are not of great importance for GCEs; these curriculum credits could be reduced.

With respect to the remaining areas, although neither the number of Master's theses completed nor the number of graduates employed in them is high, the number of curriculum credits is well-suited to needs because these areas make important contributions to the development of graduates' essential skills.

CONCLUSIONS

Analysis of the curriculum, Master's theses presented and the results of our survey show that Cartography is graduates' main work area and that it would be advisable to increase curriculum credits in this area. Similarly it would be advisable to increase the curriculum credits in GIS and Remote Sensing areas. A very high percentage of theses are written on the subject of Infrastructures, but only a few graduates work in this area. Thus, it does not seem advisable to increase Infrastructures curriculum credits. Photogrammetry is the area with the highest number of curriculum credits and, while the number of Master's theses written and of graduates working in this area is high, the number of curriculum credits seems excessive. Therefore, it is considered advisable to reduce Photogrammetry credits. The curriculum credits in Displacement Measurements and Structures could be reduced as well.

According to the opinions of former students, subjects such as Web development, Microgeodesy and foreign languages could be added to the curriculum. These additions could be easily performed if they were included as optional subjects.

The job stability of the graduates, their employment rate, their rapid job placement, the improvement of their work conditions (in comparison to their previous jobs), and the opinion of the graduates about the degree curriculum all suggest that, in general, the experience with this new post-Bologna degree has been very positive and, hence, Geodesic and Cartographic Engineering should be proposed as a Master's degree in the European Higher Education Area.

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APPENDIX

Query form

A) **Demographic data**

- Name: _____
- Last name 1: _____ Last name 2: _____
- Age: _____ Sex: _____ Province: _____

B) Academic data

- Year of completion of the Geodesic and Cartographic Engineering (GCE) studies: _____

C) Data on professional exercise

- Year of your first work as GCE (If unemployed, marks 0000): _____
- Is your job related with GCE (From 0 = nothing to 5 = all): _____
- Type of contract:
  Permanent ☐ Temporary ☐ Part Time ☐ Self-employed ☐ By contract ☐
  Internship ☐ Training ☐ Civil servant ☐ Other ☐
- Line of business of the company in which you work at the moment (indicate all that apply):
  Cartography ☐ Geodesy ☐ Surveying ☐ Remote sensing ☐ Cadastre ☐
  Consulting ☐ Metrology ☐ GIS ☐ Sales ☐ Telecommunications ☐
  Civil Engineering ☐ Hydrology ☐ Research ☐ Quality Control ☐ Fleet Control ☐
  Aid Services ☐ Central administration ☐ Regional Administration ☐ GPS ☐
  Town Administration ☐ Faculty ☐ Photogrammetry ☐ Environment Teaching ☐
  Space Systems ☐ Design ☐ Software ☐ Land Planning ☐ Others ☐
- Company's number of employees:
  1 to 5 ☐ 6 to 10 ☐ 11 to 50 ☐ 51 to 100 ☐ 101 to 500 ☐ more than 500 ☐
- Job:
  Manager ☐ Administrative ☐ Project leader Senior Engineer Team leader ☐
  Engineer ☐ Consulting engineer ☐ Specialist ☐ Sales representative Owner Others ☐
- Experience in the job:
  less than 6 months ☐ from 6 months to 1 year ☐ from 1 to 2 years ☐ from 2 to 3 years ☐
  more than 3 years ☐
- If you have had a previous position indicate line of business (according to previous classification):
  _____
- GCE degree has served to improve your work conditions:
  YES ☐ NO ☐
- Have you some other secondary labour activity:
  YES ☐ NO ☐
- Do you believe GCEs receive lower wages than graduates in other engineering fields:
  Nothing ☐ Little ☐ Rather ☐ Much ☐ Sometimes ☐
- Why did you choose the profession of Geodesic and Cartographic Engineering:
  Vocation ☐ High employment ☐ Work Conditions ☐ Family Tradition ☐
  Employer requirement ☐ Increase academic degree ☐ Others ☐

D) Opinion about the GCE profession

- Main problems of the profession that you appreciate in the labour market:

  Order from 1 = very important to 9 = low important

  Presence of no professionally qualified competitors ☐ Poor skills ☐ Society value ☐

  Work Conditions ☐ Courses offered Low Hiring Ignorance of the Profession ☐ Others ☐

- Personal Satisfaction:

  Mark all that apply

  I feel valued ☐ It is not what I hoped ☐ I have needed more skills ☐

  I do not feel valued ☐ I can develop professionally ☐ Not economically valued ☐

- Abilities that a Geodesic and Cartographic Engineer must have:

  Mark all that apply, according to your criteria and professional experience, from 1 = low to 15 = high.

  Initiative ☐ Communication (oral/written) ☐ Managerial ☐ Responsibility ☐

  Team work ☐ Curiosity ☐ Critical Reasoning ☐ Synthesis and Analysis ☐ Creativity ☐

  Independence ☐ Organized ☐ Decided ☐ Leadership ☐ Languages (English) ☐

- How would you evaluate the skills developed in the university, in comparison with your work needs?

  Mark all that apply

  Very deficient ☐ Very good ☐ Not good enough ☐

  Good enough ☐ Not enough practical skills ☐ Not enough theoretical skills ☐

E) **Opinion on the subjects of the Curriculum**

- Considering your work experience, personal opinion and the way they were taught, evaluate the following subjects:

  –1: Reduce hours **0:** Remain unchanged **+1:** Increase hours **+2:** Increase practical part

  –E: Eliminate from the curriculum **+A:** Add to the curriculum

  Advanced Geodesy ☐ Microgeodesy ☐ Geodesic Networks ☐ Physical Geodesy ☐

  Geophysics ☐ GPS ☐ Applied Geography ☐ Remote Sensing ☐ Advanced Mathematics ☐

  Cadastre ☐ Numerical Algorithms ☐ Environ. engineering ☐

  Computational photogrammetry ☐ Digital Photogrammetry ☐ Data bases ☐

  Non-Cartographic Photogrammetry ☐ Computer Programming ☐ Civil engineering ☐

  Differential Geometry ☐ Advanced Physics ☐ Law ☐ Computer graphics ☐

  Web development ☐ Infraestructures Seismic engineering ☐ Metrology and Instrumentation ☐

  GIS ☐ Image Theory ☐ Cartographic Production ☐ Geoestatistics ☐

  Engineering Projects ☐ Deformation Control ☐ Geomorphology ☐

  Mathematical Cartography ☐ Land Planning ☐ Hydrology ☐ Thematic Cartography ☐

  Business Administration ☐ Gravimetry ☐ Geomagnetism ☐ Observation Adjustment ☐

  Foreign Languages ☐ Others: ☐

_____ ____ _____ 2007

Thanks for your collaboration

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