SELECTION OF BASIC TOPICS FOR THE KNOWLEDGE OF STATISTICS IN ENGINEERING

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Abstract: Royal Decree 1393/2007, which regulates official university teaching, considers Statistics as a subject which is "basic to an education in engineering and technical subjects". It is therefore particularly important to analyse the content of this subject and the manner in which this knowledge is learnt by students at the Madrid Polytechnic University (UPM). It is also useful to establish the minimum common knowledge necessary to carry out the activities required in the fields of engineering and architecture.

A project has been developed through the **Agency for Quality, Accreditation and Prospective of the Universities of Madrid** (ACAP) to analyse students' knowledge of this subject in the final year of their degree course.

To determine the basic knowledge of Statistics that every engineer needs to have, a preliminary questionnaire was developed consisting of a large number of items grouped into blocks of topics. Then, from among these initial questions a panel of experts selected the questions to be included in the definitive questionnaire given to the students in the different specialities in order to evaluate their minimum knowledge of Statistics.

The panel of experts was constituted with 9 teachers of Applied Statistics in various Spanish and Latin American universities and engineering courses. To avoid any bias in the results, teachers from the UPM were not included. The questionnaire was sent and answered via e-mail. It was accompanied by two signed letters explaining the object of the project which was to be carried out and certifying the support of the ACAP for this project.

The initial questionnaire prepared by the project team contained 10 multiple choice questions on the 8 topic blocks considered of greatest importance. The experts had to assess the topic blocks and then select four questions from each block. The idea was to obtain a questionnaire with a maximum of 20 items to conduct the evaluation.

The following topic blocks were chosen by the experts as being the most important: descriptive statistics, sampling and estimation, hypothesis tests, and generalised linear model. The 5 questions chosen were those selected by the greatest number of experts; any ties were resolved by the statistics professors participating in the study.

Key words: experts panel, questionnaire, assessment, statistics.

1. Introduction

The subject of statistics is particularly important due to its application in engineering and technical fields (exploratory data analysis, experimental design, quality control and process control, stochastic processes, reliability engineering...).

The knowledge of Statistics required by graduates to exercise their profession depends on the work they are expected to carry out.

The adaptation of university studies to the European Higher Education Area (EHEA) makes it necessary to re-evaluate the knowledge, skills and abilities that students will be required to acquire in the different subjects on the syllabus for each degree course. It is also helpful to establish the minimum common knowledge that must be learned in order to develop the activities necessary for engineering, architecture and technical subjects. A questionnaire was prepared containing most of the topic blocks taught in the degree courses at the UPM, and with the help of a panel of experts made up of statistics teachers from different universities (both Spanish and Latin American), a list was obtained of the basic areas of knowledge in Applied Statistics.

2. Methodology

The methodology used in this work consisted of forming a panel of experts to evaluate a questionnaire regarding the knowledge of statistics of graduates in engineering and technical degree courses. The results were applied to the design of a questionnaire on the basic knowledge in the subject.

2.1. Selecting the panel of experts

The panel of experts was constituted with teachers of Applied Statistics in various universities and engineering and technical courses.

The questionnaire was initially sent to several teachers meeting the requirements in several different universities, not including the Madrid Polytechnic University, in order to avoid any bias in the answers.

The questionnaires were sent by e-mail. They were accompanied by a letter of introduction signed by the project researchers and another from the president of the ACAP in order to encourage the subjects' participation, as the questionnaire proposed is fairly extensive, although it does not take long to answer.

The panel of experts was ultimately made up of nine teachers, of which only 2 belong to the same university, although to different degree courses.

Figure 1 shows the composition of this panel, according to the courses taught by the panel members.

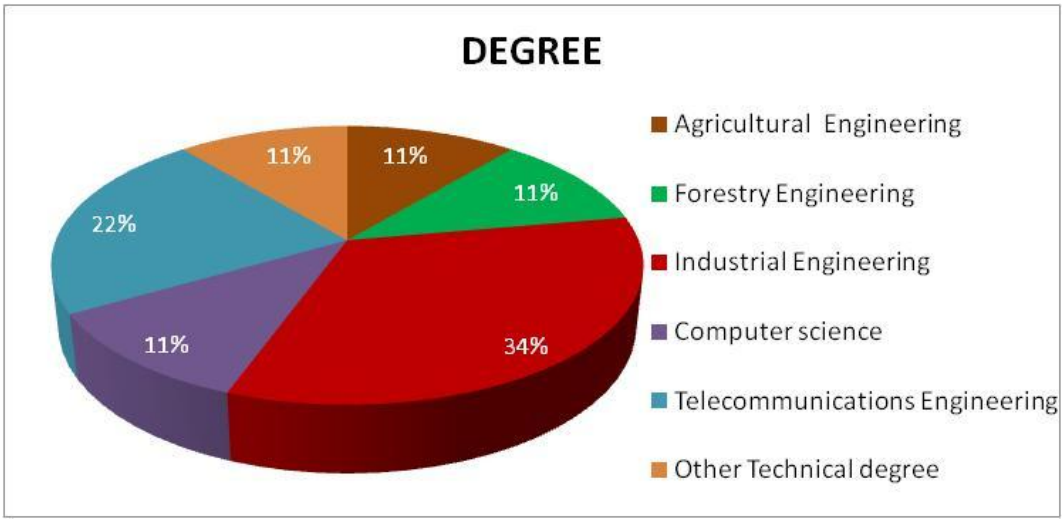

Figure 1: Composition of the panel according to the degree in which they teach Statistics.

The greatest proportion corresponds to teachers of Industrial Engineering (34%) and Telecommunications Engineering (22%).

It was not possible to include any teachers of subjects relating to construction engineering (Civil eng. or Architecture).

Figure 2 shows the composition of the panel according to the country where the panel members teach.

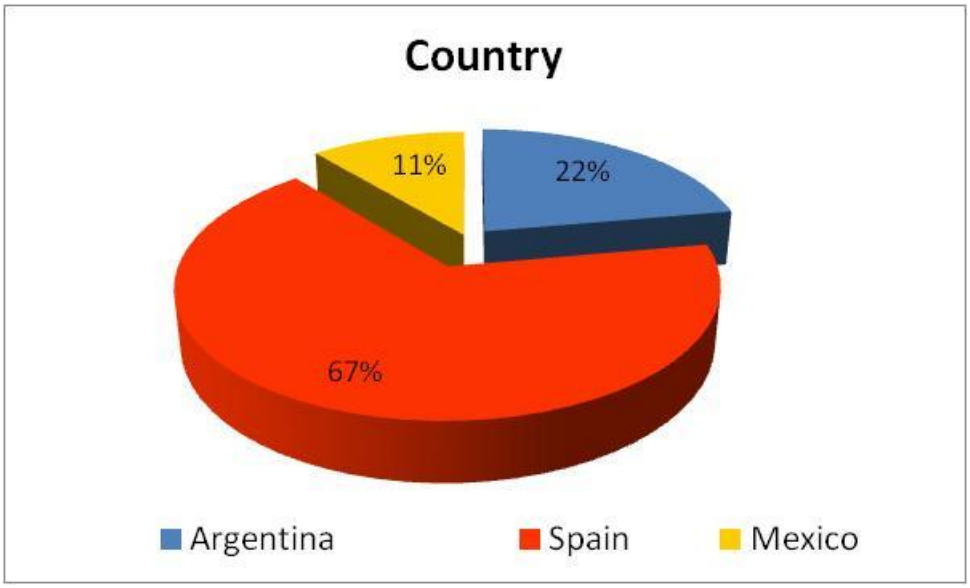

Figure 2: Composition of the panel of experts according to country.

Three teachers from Latin-American universities were included on the panel of experts.

The remaining 67% teach in Spanish universities.

Figure 3, shows the composition of the panel according to their area of knowledge.

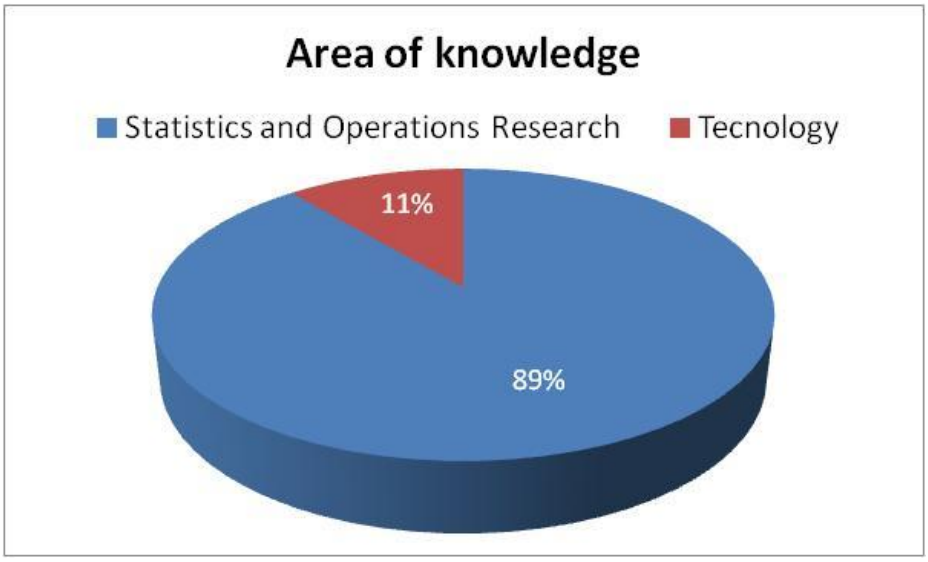

Figure 3: Composition of the panel of experts according to their area of knowledge.

89% of the experts on the panel belong to the knowledge area of Statistics and Operations Research.

The composition of the panel with regards the subject of the members' doctoral degree is more diverse, with the greatest representation of doctors in Engineering (45%) and doctors in Mathematics (33%) as shown in Figure 4.

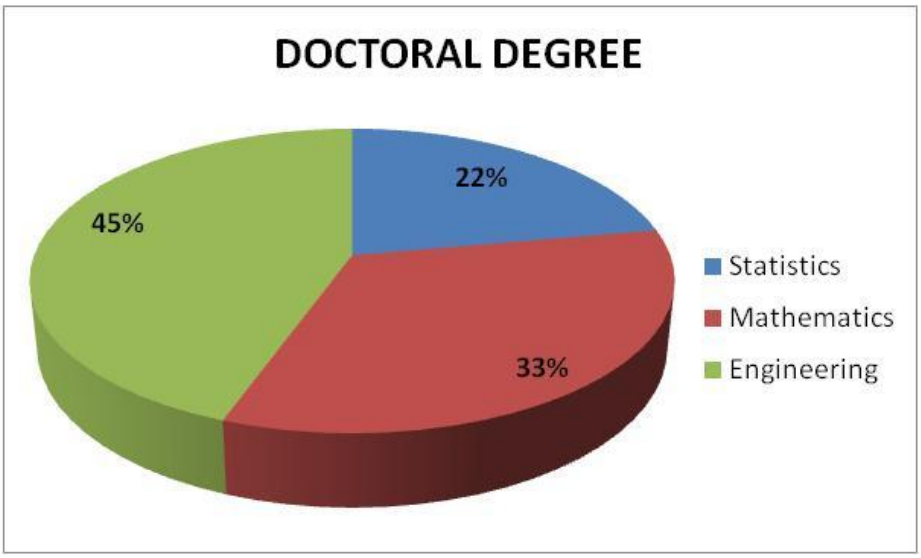

Figure 4: Composition of the panel of experts according to their doctoral degree.

2.2. Design of the questionnaire

The questionnaires sent to the experts contained most of the blocks of topics which are taught in the degree courses in the UPM, either explicitly, or, as in the case of the Statgraphics practical classes, within each subject, with graphs or program results. These

topic blocks are: Descriptive Satistics, Probability, Sampling and Estimation, Hypothesis testing, Generalised Linear Model, Experimental Design, Stochastic Processes and Multivariate Analysis.

The experts had to assess the topic blocks and specific questions on these topics. The objective was to obtain a questionnaire of 20 items so that it would not take too long to complete.

The first task of the experts was to choose between the topic blocks. The choice was based on the concept of preference ordering of decision-making [2].

Ten multiple-choice questions were then designed for each topic block (a total of 80 questions which were to be assessed by the experts). The questions were multiple-choice and offered 3 possible options with a single correct answer. There were easy questions on types of variable, central values, probability distribution; and more difficult questions on estimation, interval estimation, hypothesis testing, analysis of variance, linear regression, multiple regression and experimental design.

The experts were asked to indicate which four questions in each block they considered the best for assessing the knowledge of Applied Statistics required by an engineer or technical graduate.

3. Results

With the information provided by the nine experts, an additive value function [2] was created, in which the value of each topic block was obtained from the total sum of the number of the order assigned by the experts. The minimums in the function corresponded to their order of importance; that is to say, the lower the value, the greater the importance.
The 4 blocks with a lower value function than the rest were selected for the design of the questionnaire. Table 1 shows the result of the value function for the 8 topic blocks.

Table 1: Values of the value function for the 8 topic blocks.

BLOCKS	VALUE FUNCTION	ORDER OF IMPORTANCE
Descriptive statistics	23	1
Probability	54	7
Sampling and estimation	38	4
Hypothesis testing (HT)	23	1
Generalised linear model (GLM)	27	3
Experimental design	40	5
Stochastic Processes	68	8
Multivariate Analysis (MA)	51	6

The blocks for Descriptive statistics and Hypothesis testing had the greatest importance (with the lowest value function). Stochastic Processes and Probability are the blocks with the greatest value function, although topics corresponding to Probability are the most frequently taught in the UPM. Figure 5 shows the value function for all the blocks.

The following blocks were chosen for the knowledge test:

- Descriptive statistics
- Sampling and estimation
- Hypothesis testing
- Generalised linear model

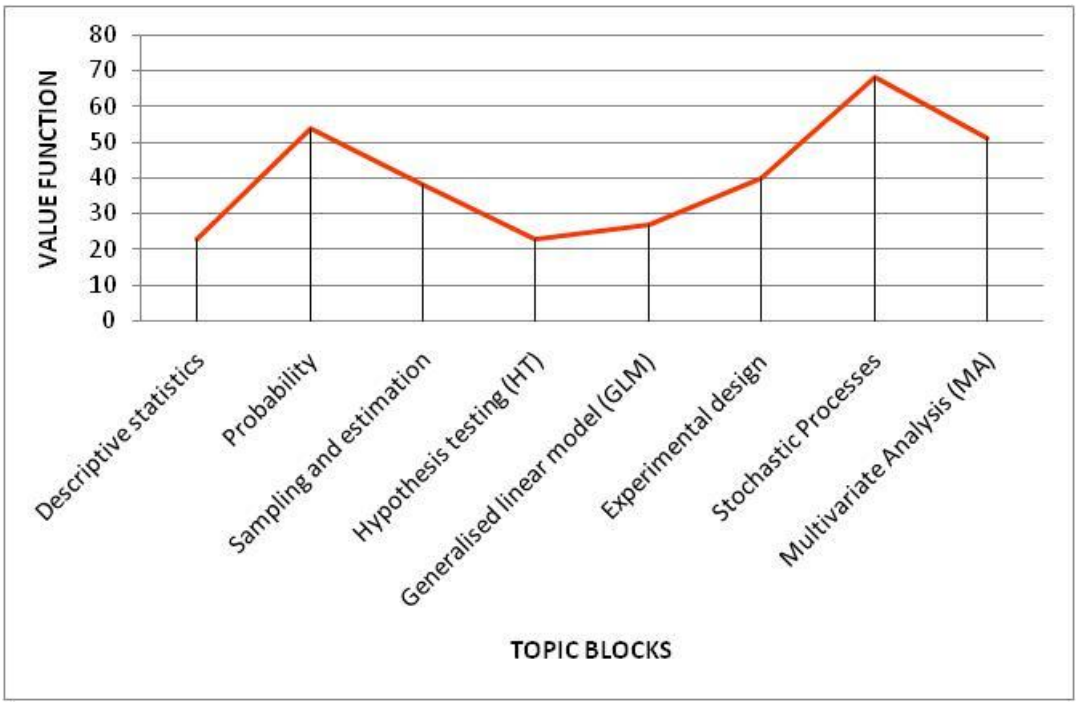

Figure 5: Value function for the topic blocks.

Within each topic block, the questions considered to be the best for assessing the knowledge to be acquired by the students were selected by counting the number of experts who considered these items suitable. The overall results of the assessments are shown in Table 2, with the items selected by 5 or more experts highlighted. In most of the blocks there were 4 items with a value of greater than or equal to 5. Only in Experimental design were there 3.

Table 2: Number of experts who selected the items.

Blocks / ITEMS	1	2	3	4	5	6	7	8	9	10
Descriptive	3	3	7	0	1	0	6	2	7	7
Probability	2	2	1	6	6	3	5	4	6	1
Estimation	5	0	1	6	8	4	3	0	4	5
HT	5	4	3	5	5	4	5	1	2	2
GLM	7	2	5	5	6	4	1	3	0	3
Design E.	6	6	2	3	3	3	2	3	1	7
S. Processes	6	3	5	2	3	3	1	2	6	5
MA	4	6	1	7	0	7	0	9	1	1

It was decided to include 5 items per block, making a total of 20 questions. The statistics teachers taking part in the questionnaire resolved any ties.

4. Conclusions

A questionnaire containing 20 questions divided into 4 topic blocks was developed in order to determine the degree of basic knowledge of statistics in graduates from the UPM. The 4 topic blocks were as follows: Descriptive Statistics, Sampling and Estimation, Hypothesis Testing, and Generalised Linear Model.

Each block contains the 5 questions selected from the initial questionnaire by the greatest number of experts on the panel.

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