A CASE STUDY OF TEACHING STATISTICS IN ENVIRONMENTAL SCIENCE STUDIES

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The consciousness of the importance of environmental problems is increasing in society worldwide. The statistical methods in this context are very useful tools for data analysis, evaluation of impact on the environment and decision making. This work considers the current situation of environmental science studies in Spain and discusses the role of statistics in them. A course organization and its teaching methodology, in which theory and practice has been integrated, is presented.

TEACHING STATISTICS IN ENVIRONMENTAL SCIENCE STUDIES: CURRENT SITUATION IN SPAIN

In universities throughout Europe, environmental education is characterized by expansion and change. The increased emphasis on the environment is requiring universities the most appropriate means of meeting the wide-ranging needs of students, employers and society. As a consequence of this, there is a great demand for different types of university courses concerned with the environment.

There are around 57 University Institutions in Spain. Most of them offer updating and training courses in specific environmental subjects at postgraduate level. However, only in nine of these institutions, new undergraduate courses in Environmental Science are taught. These courses have been introduced with the new Spanish University Syllabus, and in two universities will begin next academic year. Most of the Institutions teach a six semester Diploma and incorporate four extra semesters in order to get the Bachelor in Environmental Science. Some universities, such as the Polytechnic University of Valencia, focus only on the last four semesters as a specialization. Graduate students from other Diploma, Engineering or Bachelor degrees may sign on for this specialization.

The number of institutions in Spain teaching Environmental Science is still small, but taking into account the importance of this subject in our society, it will keep increasing. Therefore, this is a most appropriate moment in order to talk about the role of Statistics in this science.

The use of Statistics as an information base for modelling and research is well established in the social, industrial and economic fields. In contrast, the development of Environment Statistics, which is also known as Environmetrics, is quite recent. No branch of Statistics is developing at such a pace. Growing interest in environmental change is

being demonstrated by society worldwide, and close monitoring and detailed description of the environment is needed. This requires properly applied statistical methodology to ensure well-conducted data collection and assembly, and also careful presentation and interpretation (Barnett and Riley, 1995). Therefore, training in appropriate statistical techniques is fundamental to Environmental scientists and engineers.

Statistics is included as a required subject in all the curricula of Environmental Sciences in Spanish universities. It is taught in the third semester in universities which have only the Diploma degree. Those which also offer the four semesters of specialization, include another advanced statistics subject in the fifth semester. Finally the universities which have only the four semester specialization include statistics in the first semester of this specialization. The allocation of time is variable: around 4-8 hours per week. The teachers involved in this subject are within Statistics and Operational Research, or Applied Mathematics knowledge areas.

The quantitatively most important techniques included in their curricula are: Descriptive Analysis, Probability, Statistical Inference, Sampling, Analysis of Variance and Regression Models. These course contents are similar to that recommended in a 1989 Conference on Statistics and Probability in the training of Engineers (organised by ABET, Accreditation Board for Engineering and Technology), but in the context of environmental problems other techniques are also useful. Environmental observations usually show different types of variation, measurements are likely to be multivariate and often range over space and time. In some cases (4 Institutions) optional subjects on advanced statistical techniques are also taught (Multivariate Analysis, Longitudinal Models, Time Series Analysis).

In the analysis of environment data complex spatial and temporal models are sometimes needed, not just basic spatial methodology (for example kriging) on the one hand, or mere univariate time series on the other. It is also important to develop extensive datasets to monitor health and population demands, biological change and species diversity and to provide meaningful indicators of sustainability. Frequently, poor quality in available data is found. Special forms of data inputs often need to be handled, for example, in the form of geochemical mapping, remote sensing and international networking of information, so that accurate evaluation of environmental change and its impact can be done. Those are new research areas in the field of Environmental Statistics, and in the future these techniques should be included in the environmental curriculum.

COURSE ORGANIZATION FOR STATISTICS IN ENVIRONMENTAL SCIENCE AT THE POLYTECHNIC UNIVERSITY OF VALENCIA

The Polytechnic University of Valencia (UPV) currently has 14 Institutions, 1,300 teachers and around 35,000 students. The Environmental Science studies were approved in January 1997 as a four semester specialization course to get the Bachelor degree. They are assigned to the Civil Engineering School and are taught at the UPV in Valencia and at the University School in Gandia, which administratively depends on the UPV. Statistics is included in the first semester of the specialization, with 5 hours per week (3 for theory and 2 for practice). Approximately 120 students have been involved in this course (70 students in Valencia and 50 in Gandia) during the 97/98 academic year. 20% of the students had a degree in Engineering (Civil Engineers and Agricultural Engineer), 69% had a Diploma in Agricultural studies, Industrial and in Civil Engineering, and 11% had a bachelor in Biology or Chemistry. The working team consists of two teachers (the authors of this paper) who are members of the Statistics and Operations Research Department of the Polytechnic University. Our backgrounds and research activities mainly concern statistics applied to engineering.

The course organization follows the objectives established by the Educational Innovation Project, which appeared in 1989 in the UPV to improve the quality of the teaching/learning process (Romero et al. 1995). These objectives are:

- To make students acquire the sufficient knowledge so that they may formulate, solve and interpret complex problems in relation to making decisions, which may be approached from the statistical techniques.
- To integrate Theory and Practical work, by means of the statistical techniques studied to real world cases and to their solving with the appropriate software.

During the first semester of the academic year 1997/98, we have introduced a methodology and a course organization for teaching Statistics in Environmental Science to attain these objectives. To encourage the students' active participation, we have reduced the time spent in lecture classes and increased individual work and discussion. The teacher plays the role of "facilitator of learning" (Romero et al, 1995).

The general procedure used in the teaching/learning process of the different statistical techniques is made up of three stages. The first stage lasts two hours and

consists of explanation by the teacher of the basics of a particular technique in the classroom, illustrating it with a real problem. The second stage, lasting one hour, involves a discussion of the problem using the STATGRAPHICS statistical package on a portable computer with a liquid crystal display screen. These are valuable tools since they easily display tables and graphs that help students to intuitively understand the theoretical concepts. Today, computers give us a chance to analyze real data more efficiently than we formerly could; therefore, it is essential to integrate suitable statistical software into the teaching of statistics. The software STATGRAPHICS is easy to use, it has very good quality graphs, and it has implemented the most common statistical methods taught during the course.

The third stage lasts two hours and takes place in a computer room with twenty PC´s. In these laboratory classes the students work in teams of two or three people. Students appear to learn better if they work cooperatively in small groups to solve problems and learn to argue convincingly for their approach among conflicting ideas and methods. A Garfield (1995) points out "...Group activities provide opportunities for students to express their ideas both orally and in writing form, helping them become more involved in their own learning". In the computer room the students carry out practical tasks using STATGRAPHICS. A written report, using non-technical language, must be prepared at the end of this session.

The students involved in the course have a Diploma, Bachelor or Engineering degree and have already studied a basic statistics course (Univariate Descriptive Statistics, Probability and Probability Distributions). Then, the contents of the course are the following: Sampling techniques, Inference (Parametric and Nonparametric Inference), Analysis of Variance, Descriptive Analysis of Time Series and Introduction to Multivariate Analysis (Principal Components Analysis, Cluster Analysis).

In spite of time limitations, we include in our syllabus advanced topics such as data transformations, dummy variables in multiple regression models, and Multivariate techniques. Although we are aware of their importance in the training of environmental scientists and engineers, we do not teach Time Series Modelling (ARIMA, spectral analysis) and Spatial Statistics. A time limitation has prevented us from including them in the statistics course.

CONCLUDING REMARKS

Some difficulties arise in implementing this teaching approach. An important obstacle is the extra work load for the teachers, especially during the first year, because teaching materials and practical tasks have to be prepared. Although there are very important references on statistics in environmental science (see for example Berthouex and Brown, 1994), there is no textbook which can be used for the course as planned.

It is important that the teachers´ background and research activities concern environment statistics. Environment problems are interdisciplinary and global, and they can only be solved by determined international collaboration. Therefore, the involvement of the academic staff in international research programmes also has a key role in enhancing the quality of teaching, learning and research in universities.

Following the general methodology presented in this work, one endeavours to potentiate the student´s active participation in the classes. Therefore, the best result would be to get a positive student´s attitude towards the subject. In order to evaluate the results of this experience, at the end of the year the students have completed a survey on the course, and its results will be used as feed-back information to improve the teaching approach. Statistics has obtained very good results in these opinion surveys and is considered one of the most useful subjects because of the interest it arouses and its usefulness in their future careers.

We are also planning to design a follow-up questionnaire to get information during the next years concerning the students use of statistics in their future work place. An assessment of this type would provide a powerful validation of the course. Then we shall be able to verify whether our students have incorporated the statistical techniques into their knowledge, and applied them in the context of environment problems.

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