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A multidisciplinary graduate level project-based programme in applied statistics

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The use of a project-based approach for designing a one-year graduate level programme in applied statistics is addressed. The pedagogical approach, academic setting, and learning activities are described in a multidisciplinary context. Some comments on implementation of such a programme based on the results from five successive graduating classes at the University of Veracruz (1994–2000) are included.

1. Introduction

There seems to be a general consensus that statistics service courses can be most effective under the following scenarios: (i) in communicating the value of statistics for solving real world problems; (ii) in motivating the learning of key statistical concepts; and (iii) in promoting the appropriate use of statistical methods and techniques in a wide variety of scientific and professional activities. Making the course more data oriented, getting the students involved in solving real-world problems in the context of their discipline, and making it less mathematical and more software supported, to ease the technical and computational burden, are recommended as alternative approaches in order to improve the state of statistical education [1–4]. 'In context', 'participative', 'cooperative' and 'technologically supported' learning are the innovative elements for designing and implementing service courses in substantive fields [5]. However, very little has been reported about the curriculum design in graduate level applied statistics programmes.

Traditional graduate-level programmes in statistics (MS or PhD) are normally designed for undergraduate majors from various substantive fields, but they typically have a strong mathematical and theoretical component and are oriented towards producing statisticians to play a role of leadership for teaching and research in statistical science. Currently, statistical training to prepare well-qualified users of statistical methodology for decision making, planning, administration, and implementing improvement processes in industry, government and research institutions in different substantive fields is very urgently needed in Latin American countries and particularly in Mexico [6]. In order to meet this growing demand, a one-year graduate level diploma programme in applied statistics was established at the National Autonomous University of Mexico (UNAM) in 1982. Following the growing popularity of this programme and the recommendation of the Statistics Education Committee of the Mexican Association of Statistics

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(AME), a similar programme was also adapted at the University of Veracruz, with several substantive changes in the programme being offered at the UNAM.

The Faculty of Statistics at the University of Veracruz has had a long tradition of preparing applied statisticians for positions in government, academia and industry in the Veracruz region in Mexico. A bachelor's degree in applied statistics has been offered since 1968 and a one-year graduate level diploma programme in statistical methods (Especialización en Métodos Estadísticos) was established in 1990. The graduate programme has a multidisciplinary focus and is primarily designed for professionals from a variety of disciplines, including biology, medicine, agriculture, engineering, education, sociology, economics, psychology, among others. The main objective is to prepare 'good' users of statistical methodology who are conceived as applied scientists, professionals and researchers, and intelligent consumers of statistical products and services. Table 1 presents an outline of the curriculum and the courses being offered.

This programme is not just a series of traditional courses being offered in isolation; but, in its design and development, it makes use of a project-based approach at several levels of complexity. All of the courses are data driven and oriented towards solving real-world problems; and all learning experiences take place under 'in control' scenarios. This implies that the entire classroom time is devoted to activity-based learning with minimum use of lectures and other instructions of theoretical nature. For the statistical application courses (Applied Statistics I and II) a project-based approach is used for presenting the learning activities, and it is implemented via a tutoring scheme. The purpose of this paper is to describe the learning principles involved and the procedures for developing the curriculum, as well as to present a brief outline of the programme. We also include a description of the academic instruction and learning activities and provide some comments on the results and experiences on programme implementation obtained from six successive graduating classes.

2. Learning with the project-based approach

Learning takes place in three distinct areas: the physical area, the logical area and the emotional area. Learning will not take place unless simultaneous changes

Quarter	Course title	Number of hours
1st	Statistical Methodology*	45
	Sampling Methods*	45
	Probability and Statistical Inference*	75
	Statistical Packages I**	30
2nd	Regression Methodology*	45
	Experimental Design and Analysis of Variance*	60
	Multivariate Methods I*	75
	Statistical Packages II**	30
3rd	Nonparametric Methods*	45
	Quality Control Methods*	45
	Multivariate Methods II*	45
	Applied Statistics I**	45
	Applied Statistics II**	45

* methodological courses, ** applied courses.

Table 1. Postgraduate curriculum in Applied Statistics at the University of Veracruz.

in all the three areas occur. There are several ways of referring to these areas, but the most common are knowledge area (logical area), abilities area (physical area) and attitudes and desires area (emotional area). Learning, considered as a change in knowledge and skills that enables new and different kinds of activities, requires a dialectical process between the rational and the emotional, but the motivation is the real starting point [4, 7].

In teaching statistics it is generally very unusual to find a course that includes all the components in a complete learning cycle. Furthermore, it is very difficult to design a successful course [8, 9]. The reason is that in a traditional educational programme, abilities and habits supported by theoretical knowledge are created, but ultimately it is the 'hand on' experience that will make the learning complete. Illustrations of complete-learning programmes are the ones designed for physicians and dentists whose practical training takes place in a real-life environment.

It should be pointed out that it is now being widely recognized that in order for special purpose statistics courses to promote active learning, they must provide students with opportunities to work with real-life problems [7, 10, 11]. That is, they must expose students to the experience of applying statistics to real-world problems, even if only after the data have been gathered. The best results, of course, are obtained when students participate in the complete project, using the so-called project-based learning [12]. This implies student participation in: (1) problem identification; (2) statement of the problem in statistical terms; (3) statistical design; (4) data gathering; (5) data analysis; and (6) presentation of results. There are logistical problems in how to accomplish this goal. The approach of students' projects has won itself many proponents [3, 13–15]; general proposals have been made about this methodology, and individual experiences documenting the advantages and disadvantages in the design and implementation of this type of learning strategy in introductory and specialized courses have been widely reported [2, 16–18].

When projects are used in the instruction process, the student can learn to apply the statistical methodology, acquire training in the use of software, develop skills in oral communication and written presentation, and learn how to draw conclusions from the results of the statistical analysis. However, there are several problems involved in applying this approach, such as excessive advisory support, and more importantly, a special instructor profile, which have been discussed elsewhere [19].

Graduate students generally tend to have a higher level of motivation and scientific maturity than their ungraduate counterparts. They normally have acquired some experiences with real life situations that require the use of statistical methods for an adequate solution. Consequently, a project-based approach was implemented for the curriculum design in a one-year graduate level diploma programme for statistical methodology users, which will be briefly described in the following section.

3. Academic programme and learning activities

Table 1 shows the list of courses and the number of hours required for each course. In all of the methodological courses (marked with *), the instruction is imparted in a fairly down-to-earth and practical manner using real-world

problems and proper methods of handling and communicating solutions. The goal is to train statistical methodology users able to make intelligent applications of statistical methods and to recognize when the situation warrants the advice of an expert in the field. In order to meet the learning objectives, all the study materials and classroom exercises are carefully designed following an integrated approach that considers: (1) the study of the practical context of the problem; (2) translation of the problem in statistical language; (3) the design of a general strategy for problem solving; and (4) obtaining conclusions and practical implications.

In teaching statistical procedures and techniques, the major emphasis is on the clear and concise formulation of the problem and the statement of statistical objectives to explore, to describe, to estimate, and to evaluate. Exercises and problems requiring extensive computations are solved using two statistical packages (STATISTICA® and STATA®). For which a series of supervised training sessions is included in Statistical Packages I and II. The major goal is to provide intensive training in providing useful interpretations of the computer output and the results of the statistical analysis.

Project design and implementation activities are developed within an integrated programme in two workshops (Applied Statistics I and II). The first course follows the protocol design, which implies the application of a series of key concepts in statistical design techniques. The students present their project ideas in a first phase. The project is delineated and written with the advisor participation in a second phase. The final phase in the course involves scheduling a meeting where the students present the definitive protocol. During the last three months in the programme, all the practical activities are directed toward implementing the protocol. A tutorial approach is used in order to control the evolution of the project. The second course is devoted entirely to discussing the periodic progresses made; and, in a final meeting, the discussion of the project results takes place. A written report is submitted and orally presented in an open session in the presence of an academic committee that evaluates the findings and the quality of the work.

In order to provide the adequate comprehension of the project-based approach, a series of conferences is organized during the implementation of regression and multivariate methodology courses. Applications of statistical methodology processes are discussed in the general context and in several specific situations. The role of a statistical design, including sampling, experimental design and observational studies, is highlighted. Strategies for data analysis are discussed with emphasis on the role of initial data analysis, statistical modeling and multivariate analysis. A project-based approach is used in the implementation of all methodology courses after the first quarter, where the students work in groups, which facilitates collaborative learning. We discuss project formulation, project presentation, and design and project implementation strategy with emphases on the specific methods that courses cover; in addition to presenting exploratory techniques for data diagnosis and description. In each of these courses a meeting is organized for final presentations. Where practical recommendations and interpretations in the context of the real world problem are pointed out. To provide an additional training in writing reports, we have used a simple report model [20, Chapter 20; 21, Chapter 12]. Which is documented and discussed in the context of the second applied statistics course.

Undergraduate concentration	Class														Total	
	1994		1995		1996		1997		1998		1999		2000			
	En	Gr	En	Gr	En	Gr	En	Gr	En	Gr	En	Gr	En	Gr	En	Gr
Social Sciences	0	0	2	2	1	1	4	2	2	1	2	1	8	6	19	13
Biological and Health Sciences	7	4	6	4	1	1	9	7	4	3	8	5	19	13	54	37
Engineering and Physical Sciences	2	1	1	1	2	2	0	0	3	1	3	2	3	2	14	9
Mathematics, Statistics and Computer Science	29	23	22	16	15	10	22	16	19	18	20	18	43	33	170	134
Business and Economics	2	2	4	1	3	2	2	1	2	1	5	4	4	2	22	13
Total	40	30	35	24	22	16	37	26	30	24	38	30	77	56	279	206

Table 2. Breakdown of statistics on enrolment (En) and graduation (Gr) by the class year and the undergraduate concentration.

4. Programme implementation results

Seven graduating classes in our programme have been successfully completed since its inception in 1994. Table 2 presents some statistics on enrolment and graduation classified by the area of undergraduate concentration.

We emphasize statistical application processes in our programme; however, several projects are oriented towards presenting statistical theory and methodology with illustrative examples in the form of monographs, and term papers. Inasmuch as a large number of applied statistics professionals enrol in our programme with a view to improving their practical skills, the advisor usually recommends an application-oriented project, highlighting developments in statistical methodology. For this purpose, the written reports are classified into a number of categories as shown in table 3. The areas of statistical methods employed in the project implementation are displayed in the bar chart in figure 1.

The main problem in using the project-based approach in our programme is the difficulty in identifying the project topic when the students have no previous experience in their respective fields of study. The advisor's responsibility is to delineate each individual project and supervise its implementation as elaborated in the student proposal. When there is no prior student proposal, the advisor assists

Undergraduate concentration	Category of written report			
	Report of a case application	Monograph	Methodological contribution	Total
Social Sciences	12 (92)	0 (0)	1 (8)	13
Biological and Health Sciences	34 (92)	2 (5)	1 (3)	37
Engineering and Physical Sciences	7 (78)	1 (11)	1 (11)	9
Mathematics, Statistics and Computer Science	92 (69)	35 (26)	7 (5)	134
Business and Economics	9 (69)	3 (23)	1 (8)	13
Total	154	41	11	206

Table 3. Frequency (%) of the category of written reports by undergraduate concentration (1994–2000).

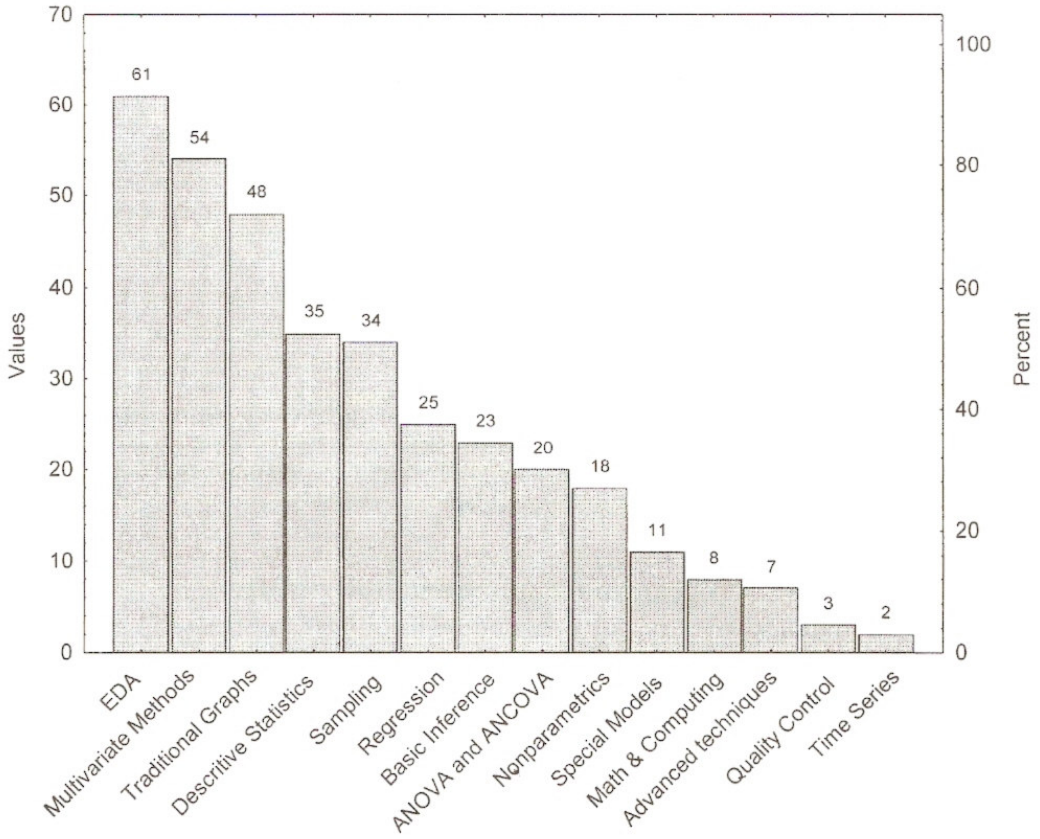

Figure 1. Bar chart showing frequency (%) of statistical methods employed in the projects (1994–2000).

the student in choosing a proposal from his/her topic preferences and/or some other academic applications. When the student has no prior practical experience whatsoever, the project tends to be somewhat insipid and artificial in nature, which is contrary to the philosophy of the programme.

The goal of our programme is to train quality statistical methodology users who are conceived as competent scientists and researchers, valuable professionals, and the best allies of our statistical profession.

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