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Disseminating Significant Learning in Statistics Service Courses

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Abstract- Teaching Statistics is changing in higher education. Non traditional statistics service courses consider learning activities allowing students to get involved in real-world problems, by using methods and procedures for solving problems. Several approaches have been proposed in order to develop statistical thinking in action using the so-called problem based learning strategies .This paper reviews theoretical and practical considerations in using the project-based approach for designing and implementing statistics service courses and training programs in applied statistics, followed by a review of the role of statistics in the research process. Several cases are commented in order to point out the key aspects that guarantee the successful implementation of the proposals.

Keywords: Statistical education, Experience-based learning, Statistical thinking, Training for statistics users, Statistics in higher education.

Introduction

Statistics is widely recognized as a highly useful and practical methodology with applications in several fields such as agriculture, animal breeding, applied genetics, biology, econometrics, education, engineering, medicine, quality control and environmental and social sciences, among others. A 'statistical culture' comprises a variety of key concepts and principles that allow the development of the so-called statistical thinking. Traditional statistics service courses are generally designed and taught using different teaching strategies, but are deficient in considering learning activities which allow the students to get involve in real-world problems, to use methods and procedures with real life data sets, and to apply statistical methodology to obtain conclusions and recommendations in the context of the research problem (see, e.g., Pollock and Wilson, 1976; Brogan and Kutner, 1986; Moore and Roberts, 1989; Bisgaard, 1991; Everson et al., 2008).

As Tishkovskaya and Lancaster (2012) have mentioned the major directions of the statistics education reform movement involve (a) pedagogical reforms toward development of conceptual understanding and teaching to statistical thinking and reasoning; (b) changes in the content of statistics courses, especially introductory level courses; (c) improving the instructional techniques used in statistics courses; and (d) integration of technology and computer-based methods into teaching statistics as an important tool for effective delivery of teaching and essential part of effective pedagogy.

Several approaches have been proposed in order to develop statistical thinking in action using the so-called problem-based learning strategies. The project-based approach is a general proposal for designing and implementing statistics service courses to ensure: (i) the ability to link statistics and real-world situations while applying adequately the principles, techniques, and methods for collecting and summarizing data, and to make inferences, (ii) the ability to synthesize the components of a statistical study, and to communicate the results in a clear and concise manner.

The project-based approach could be applied in any introductory or advanced statistics service course (Ojeda and Sahai, 1995; Ojeda and Sosa, 2002), but a careful planning of activities and critical choice of contents are required. In this paper, we present a variety of topics that constitute the minimum formal background in order to design and implement statistics service courses using a project-based approach. The general pedagogical model is delineated and the learning activities are summarized. The implementation of the proposal in a Ph. D. course is outlined. General guidelines to implement this approach in a graduate program are briefly described. A few comments based on our experiences about the implementation of a workshop for training teachers are also included.

Teaching Versus Learning of Statistics

People need to deal with numerical issues of practical consequences in different professions and walks of life are growing. In higher education the emphasis on problem solving and technical skills for the intelligent use of research methodologies is considered of vital importance in all disciplines at undergraduate and graduate levels. In this context, the pattern of 'extensive explanation and questioning on the part of the instructor followed by student teamwork on paper-and-pencil assignments is gradually fading out (Fey, 1979, p.494); however, the traditional view of statistics as mathematics' branch is still dominant and significantly influential in statistical education (Behar, 2001). On the other hand, statistics is increasingly being recognized as a practical discipline that deals with numbers in the context of data and makes systematic study about how to reason under uncertainty (Scheaffer, 2001). Several definitions of statistics note that it is the science of assembling, organizing, and displaying data. In this regard, we agree with Scheaffer (2002) when he observes that statistics plays an important role in allowing that to happen. The main problem in statistical education is that the instructors in statistics service courses often fail to impart an appreciation of the value of this 'research methodology', and instead promote rote

memorization by using excessive mathematical formalism and 'teaching without context'.

The problems in traditional statistics service courses have now been very well documented (see, e. g., Bancroft, 1972; Ehrenberg, 1976; Garfield and Ahlgren, 1988; Garfield, 1995; Becker, 1996; Moore, 1997; Watson, 1997; Higgins, 1999; Hogg, 1999; Gal, 2002; Garfield and Ben-Zvi, 2002; Verhoeven, 2006; Smith and Staetsky, 2007; Rassias, 2010). In order to overcome these problems, new teaching strategies for improving learning have emerged (Moore, 2000; Batanero, 2001; Tichkovskaya and Lancaster, 2010). The future direction in the teaching and learning of statistics requires taking into consideration the impact of information technologies for preparing competent statistics users for the current and future needs of all professions. In order to impart the awareness of statistical thinking in learning process, recent studies in education suggest promoting the value of data science in learning about the world (Cleveland, 2001). In light of the foregoing considerations, statistics is a set of principles and techniques employed to determine the correct research design to accurately obtain the needed information, the appropriate strategy for data analysis, and the best means for communicating the relevant results (Bishop and Talbot, 2001).

The goal of learning strategies is to affect the learner's motivational or affective state. However, learning competencies are evaluated in such a way that the learner selects, acquires, organizes, and integrates new knowledge. In several disciplines, including statistics, the learning's focus is on 'know-how' for an adequately problem solving using a variety of principles, techniques, and methods, which constitute this discipline's knowledge body (Weinstein and Mayer, 1986). In this context, several approaches for teaching statistics have emerged (Lovett and Greenhouse, 2000; Behar, 2001). There are a variety of papers in which the effects of certain technology related factors on teaching and students' learning in statistics have been investigated. For example, Chan et al. (2000) looked at the possible advantages of bringing real life examples (such as newspapers and magazines clippings, video-tapes); Leon and Parr (2000) argued that a course home-page facilitates the learning process; Boger (2001) studied the impact of using student-generated data; Cabilio and Farrell (2001) proposed a computer-based lab as a supplement to lecture; Root and Thorme (2001) asked whether community-based projects can enhance students' understanding of statistics; Spinelli (2001) compared the in-class use of computers versus calculators; Sirias (2002) investigated the use of advance organizers; Martin (2003) focused on the potential learning power of analysis; Vaughan (2003) talked about his experience of teaching statistical concepts with student specific datasets and students analyzed their heating bills. See also DelMas, et al. (1999), Jolliffe (2001). For challenges, pedagogical experience and further directions in teaching statistics see Cobb (1992), Wild (1994, 1995), Garfield (1995, 2002), Romero et al. (1995), Yilmaz (1996), Kettenring (1997), Nicholls (2001), Bessant and MacPherson (2002), Garfield et al. (2002).

The so-called project-based approach is a problem-based learning strategy (Savin-Baden, 2000).This approach is based on engaging students in solving heuristic problem that promotes learning and learning strategies, as well as general principles about how to learn, how to acquire skills in using techniques and methods and, of course, how to solve problems (Griffiths and Evans, 1976). As Harland (2002) notes, this approach encourages the development of life-long learning skills, but it requires that both, the instructor and the student, challenge their conceptions of teaching and learning. Several obstacles would have to be deposed; for example, students would be required to take control of their own learning and to cooperate through teamwork. See also Moesby (2004), Spronken-Smith (2005), Savery (2006), Rowan et al. (2007) and Marriott et al. (2009).

Learning Statistics in the Research Process

To apply statistics is like engaging in an enterprise that requires not only theoretical, methodological, and computational skills, but also an adequate understanding of a well-defined problem in order to provide precise answers to empirical research questions. Applying statistical tools involves not only the study design for an adequate data collection and the implementation of statistical methods, procedures, and techniques to analyze data to obtain the information required, but also the formation and development of effective means for communicate meaningful results (see Figure 1). In this regard, statistics is a useful methodology for all the stages of the research process, beginning with the problem formulation stage. Here, key statistical concepts and principles allow the researcher to clearly define the objectives and formulate research questions in a precise way.

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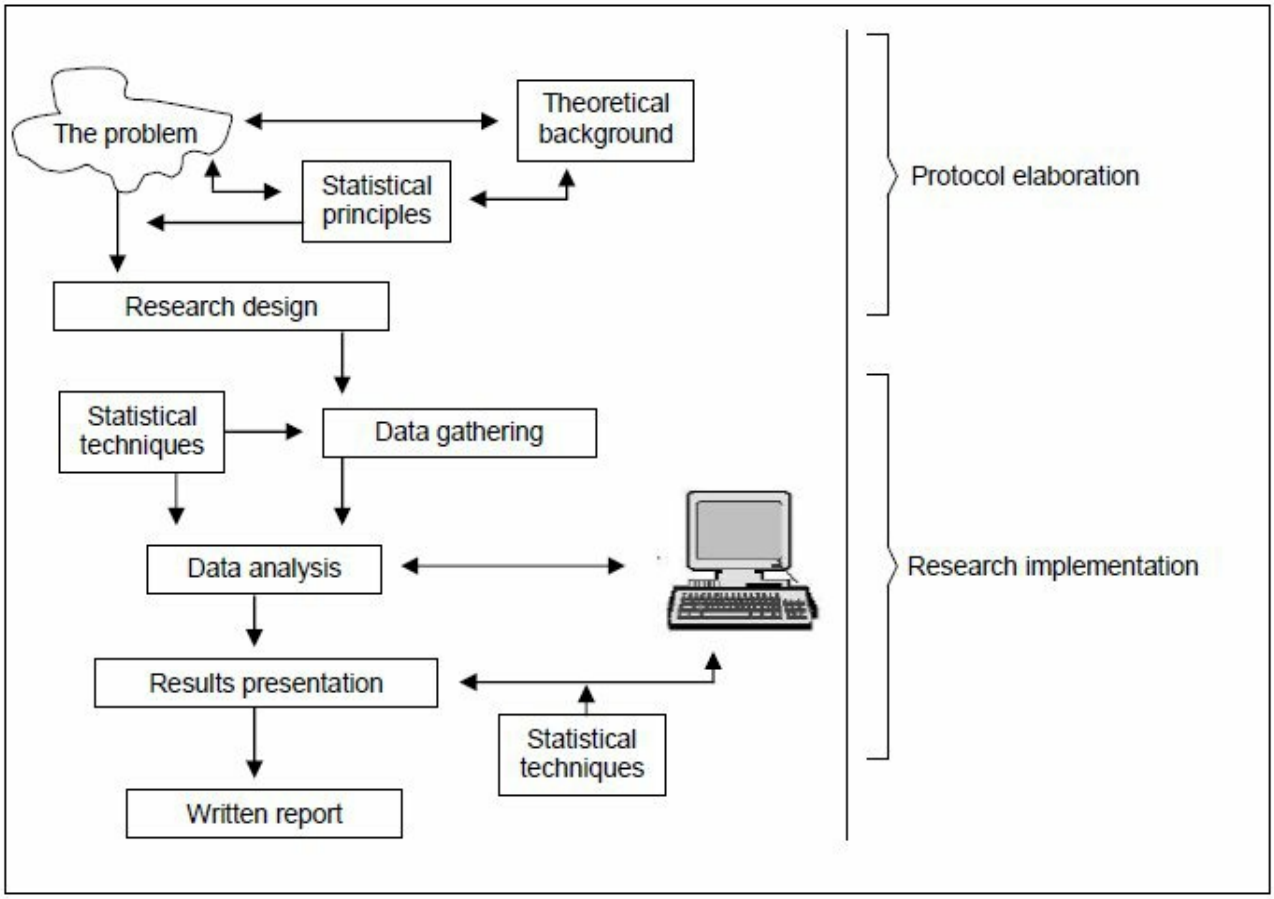

Figure 1. Statistical application process and activities in empirical research context.

The study design step is a crucial one in which the use of statistical principles and techniques leads to an adequate data collection plan. In this regard, Chatfield (1995) points out '…should an experimental design, sample survey, observational study, or what, be used? How will randomization be involved?' Decisions must be made regarding who should or shouldn't be included in the study. Are there any possible biasing factors? How well can data be generalized to another areas, or only the specific one being studied? (Holmes, 1990).

The statistical design phase of empirical research implies that you should 'plan your survey', 'plan your experiment', or 'plan your observational study', but these particular strategies haven't been yet fully delineated. However, many survey sampling and experiments design books (see, e.g., Lorenzen and Anderson, 1993; Cox and Reid, 2000; Rao, 2000; Wu and Hamada, 2009) present the principles and procedures to define an adequate research design pertaining to those kinds of studies. In observational study designs, several books about epidemiologic methods (see, e.g., McNeil, 1996; Miettinen, 2011) include a variety of considerations and guidelines; in addition, some other books (see, e.g., Goldstein, 1979; Cochran, 1983) also address this topic. Useful guidelines and references about these topics are included in Bishop and Talbot (2001).

Data analysis is a very well established statistical methodology; however, the data analysis phase in quantitative research requires a well-defined strategy in order to optimize time and effort to obtain concrete responses to research questions. An appropriate strategy for data analysis in an empirical research situation is defined by many steps (using initial data analysis and definitive analysis), which requires minimal time and effort for providing specific answers.

The essence of statistical analysis has two very well defined components: summarizing data and making inferences. These inferences might be final conclusions supported by probability statements and based on statistical models. On the other hand, conclusions from graphical displays and descriptive measures are very useful for taking appropriate actions and making decisions in the research context.

The researcher should consider the goals of empirical research (exploratory or confirmatory) and selection of statistical study (sampling, experimental or observational), by clearly defining the steps in the data analysis phase along with the statistical study, but for basics we recommend two steps: initial data analysis and definitive analysis (Chatfield, 1995). In the first step, we implement exploratory or descriptive techniques to examine univariate and bivariate data distributions, comparing groups or fitting statistical models in an informal way. In exploratory research or sampling surveys, this step produces a meaningful set of results, which allows the attainment of the main goals in the project; however, multivariate methods or complex statistical models could be necessary for final conclusions. Inferential

procedures for sampling are considered in definitive analysis used in descriptive and analytical surveys (Lehtonen and Pahkinen, 2004) and the strategy could consider complex and multivariate statistical models. For analyzing data from an observational study, many descriptive and inferential procedures are available (see, e.g., Sahai and Khurshid, 1996, Woodward, 2005) and those could be applied for definitive analysis of complex statistical models (Heck and Thomas, 2008). The general strategy for an experimental study is more popular, and here the statistical modeling process is implemented. Several popular textbooks (Lorenzen and Anderson, 1993; Mason et al., 2003; Box et al., 2005; Montgomery, 2012) present how to analyze and design experiments.

The effective presentation of important study results involves well-designed figures and tables, which implies not only additional skills in statistical graphics and communication environments, but also many key statistical considerations, and a preparation of the final report. Several handbooks or articles provide guidelines on how to prepare a written report for a research project and, following this conception of statistics, some textbooks have also recently begun to include a chapter on this topic (see, e.g., Watt, 1997; Spurrier, 2000; Ott and Longnecker, 2008).

The content and style of the written report should be in accordance with the level and sophistication of the intended audience. For an introductory service course a simple outline can be used which includes: (i) Title and summary; (ii) Project background; (iii) Study objectives; (iv) Study design; (v) Data analysis; (vi) Results; (vii) Discussion and recommendations; and (viii) Bibliography. For a public presentation of a report, careful preparation is recommended. Guidelines to prepare visuals (Power Point) should be taken into consideration. Several sources on how to obtain information about an appropriate strategy are available in many texts (see, i.e. Spurrier, 2000, Chapters 13 and 14; Hoerl and Snee, 2002, Appendix B; Ott and Longnecker, 2008, Chapter 20).

For dissemination of statistical thinking and the appropriate use of statistical tools, it is recommended the so-called project-based approach, when one is working with real-life problems in order to carry out the entire project (Hakeem, 2001; Kvam, 2000; Wild and Pfannkunch, 1999). When projects are integrated in a course, it will enable the students to learn how to apply the appropriate statistical methodology, acquire training in using software, develop skills in oral communication and written presentations, and to draw conclusions from the results of statistical analysis. In this approach, students are required to design and carry out a statistical study, meaning an application of statistics in an empirical research process involving the following steps: (i) techniques for data collection (statistical design), (ii) principles and procedures for analyzing data (statistical analysis), and (iii) methods and techniques for present results (statistical presentation). For various issues including benefits of projects associated in statistics see Scott (1976), Dolan (1979), Kanji (1979), Schoeman and Steyn (1983), Uche (1984), Fillobrown (1994) Chance (1997), Smith (1998), Halvorsen and Moore (2000), Wardrop (2000), Kurji (2002), Binnie (2002) and Thorme and Root (2002).

Project Development

A capable user of statistical methodology is an individual who uses statistical tools to deal with numerical information and draw valid inferences. This includes methods of data collection, data summarization, and data analysis, as well as communicating results of the analysis. In a statistics service course the goal is to prepare qualified users of statistical methodology; therefore an effective statistical education should endeavor towards the use of statistics for the real world applications. In order to develop a clear understanding of the relevance of statistics in real world applications, the student must work in a 'real life situation' where a well-defined problem is required to elaborate a project. The students can identify situations in his/her field of study, but also could be interested in situations related with experiences in daily life. We agree with Hirotsu (2001) when he states, "… applied statistics can be most efficiently taught when students have their own problems and motivations to find correct answers". In any case, the participant of the course needs a set of guidelines to develop a project. In this stage, the review of several examples involving different kinds of statistical studies will be useful to promote learning by transference. Practical recommendations and simple models for 'student projects' are available in several textbooks (see, e.g., Watt, 1997, Chapter 11), but we have used the scheme in Table 1, with teams of two or three students. This strategy promotes collaborative learning and provides the needed time and effort for the fieldwork.

A clear definition of the problem requires a variety of concepts and a brief description of the 'state of the art'. This background and a careful delineation of the real-world problem allow the formulation of objectives in a precise way. Depending on the type of study, various steps are taken in order to choose the appropriate statistical design. Textbooks on sampling, experimental design, or observational studies are very useful for defining the target population, the study unit, the sample size, and the randomization plan (if required). By choosing the explanatory variables (the factors and levels) and the response variables, the measurement procedure can be defined leading to the next step for gathering data. Maps, diagrams, and another additional materials for describe the statistical design can be included in an appendix.

The strategy for data analysis should be briefly described to connect the goal of procedures and techniques with the study objectives, taking into consideration the research questions under investigation. Simple procedures to gain confidence and increase the appreciation of the value of statistics as a bag of tools for solving a problem are recommended. Chronology allows the scheduling of a precise set of activities and the expected results. The availability of time and efforts needed for collecting and analyzing data are natural constraints in the implementation phase.

The description of the project is a critical phase for the implementation of the project-based approach, because it's here where the contents of the course will be incorporated towards a specific statistical application process. Statistical design techniques are briefly sketched and simple guidelines are presented, as well as project examples. In this context,

Bishop and Talbot (2001) provide a general overview and details for planning the study and, in addition, address the topics in relation with scientific methods and the role of statistics. They have listed several websites providing useful information. We have also prepared a website (www.uv.mx/mojeda) where we present some useful materials and examples to provide our students the minimal resources needed for preparing and developing a project.

Experiences with a PhD Course

Ojeda and Sosa (2002) reported the design and implementation of one semester statistics service course in a PhD program in systematics and ecology. They outlined the design of an applied statistics course using the project-based approach. Descriptions of the academic instruction offered and the learning activities undertaken were presented, as well as the results and experiences derived from the implementation of this program to a group of 15 students, each one working with a project during the course. The project-based approach was implemented in several phases. The first step was concentrated on the design protocol, where students presented their project ideas during the first three weeks of the course. Later, during the second month, the project was delineated and written in consultation with the instructor. The last step of this phase involved a formal session in which students defended their final protocol.

During the last three months of the program, all practical activities were oriented towards implementing the protocol. A tutorial approach was used to control the evolution of the project. The second phase was devoted entirely to discuss the periodic progress that has been made. In the final session, individual project results were discussed. A written report was submitted and an oral presentation was made before an academic committee responsible for evaluating the findings and quality of the work.

In order to motivate the project-based approach, conferences and workshops were organized and conducted throughout the implementation of the program. Applications of statistical methodology were discussed for both, general and specific situations. The role of statistical design, including sampling plans, experimental designs, and the design of observational studies was presented. Strategies for data analysis were discussed, emphasizing the role of initial data analysis, statistical modeling, and multivariate methods. To provide training in writing reports, a simple model format was used.

The Project-based Approach in a Graduate Program

Ojeda and Sahai (2003) described an experience in using the project-based approach for implementing a one-year graduate level program in applied statistics, where the main objective is to prepare proficient users of statistical methodology with a background as applied scientists, professionals, researchers, and intelligent consumers of statistical products and services. They point out that when projects are used in the instruction process, the student can learn to apply the statistical methodology, acquire experience in using software, develop skills in oral communication and written presentations, and learn how to draw conclusions from the results of the statistical analysis. In this context, considering that graduate students generally tend to have a higher level of motivation and scientific maturity than their undergraduate counterparts, some projects with real life applications that require the use of statistical methods for an adequate project-based approach were implemented for the curriculum design in a one-year graduate level diploma program for statistical methodology users.

The authors reported the results of ten successive generations admitted to this program. They have identified different kinds of difficulties in designing the project and conducting relevant activities using a tutorial approach. The student mentors supervised the statistical design, the strategy for data analysis, and the written report required to obtain the diploma for graduation. Finally, the authors pointed out that the main problem in using the project-based approach is the difficulty in identifying the project topic when the students have no previous experience in their respective fields of study. The mentor's responsibility is to delineate each individual project and supervise its implementation as elaborated in the student protocol. The mentors likewise assist the students in choosing a project from his/her topic of preferences and/or some other academic applications. When the student has no prior practical experience whatsoever, the project tends to be somewhat dull and artificial in nature, which is contrary to the philosophy of the project-based approach.

Training Teachers in the Project-based Approach

In the Mexican public university system several changes have recently been introduced. One of these concerns the application of research principles in offering courses; that is, using projects in the classroom that promote active learning in the context of research methodology, statistics, quantitative methods, and other related topics. This was the case at the University of Veracruz, where a large teacher training program was recently organized covering the five main campuses of the state university system.

Ojeda et al. (2002) reported on how the courses were organized and conducted using video conferences, Internet tutorials, and a home page for the availability of study materials, power point presentations, and project examples. The project-based approach was used for design a protocol in order to promote the adoption of this approach by the participating teachers. It was expected that after the conclusion of the training program, the participating teachers would be using this approach in their respective courses with active participation of their students. The design of surveys and observational and experimental studies were reviewed, and the participants were given mentoring in the selection of the appropriate design for their respective proposals. The project-based approach was implemented using a variety of examples where it was pointed out that learning can be instructive using small student projects. Readings concerning the active, collaborative, and technologically supported learning materials were recommended for the participants. In this regard, the use of the home page, the video conferences, and e-mails proved to be very helpful in achieving the goal.

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The most important benefit was an attitudinal change among the participating teachers and an appreciation of the role of statistical thinking in the research process. A comprehensive report of this experience can be found in Ojeda et al. (2002).

Concluding Remarks

The project-based approach has emerged as an important strategy in design and implementation of statistics service courses at different levels and contents. The fundamentals of learning in action and the recognized value of the experiences with real life situations are two important elements that constitute the final goals in many course curriculums. In statistics service courses or in applied statistics curriculum, the project-based approach has been growing in proponents and their followers since 1970's (see i.e. Bancroft, 1972; Ehrenberg, 1976; Griffiths and Evans, 1976). Moreover, it has lately been recognized as an important recommended strategy for conducting statistics service courses (Moore, 2000). However, the use of this approach requires a considerable knowledge of the subject matter on the instructor side to be able to mentor students in their respective classroom activities (Ojeda, 2011). Here, we have reviewed the key concepts of statistics in relation with the needs for advising in a research process. The teachers of statistics service courses in higher education would be able to adopt this view about the statistics as a 'technology' for quantitative research.

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Table 1. Project contents and guidelines.

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