ENGINEERING STATISTICAL NEEDS AND ENGINEERING CURRICULUM: AN ANALYSIS

Elena T. Fernández de Carrera
National Technological University/Litoral National University, Argentina
ecarrera@arnet.com.ar

The importance of statistical science in engineering education is a subject that no longer merits discussion. The constructivist approach in its teaching, the need to teach using problem solving, and the contribution of modern technologies to optimize this learning are accepted facts by most statistics professors. In this paper we analyze the problems present in Argentina and other countries related to WHAT is the content of the subject?, To WHAT extent do they go?, and WHEN in the core curricula, is the content included? We also analyze whether to have one course with the same content for all the engineering majors or to adapt content to the specific needs in each of area. In this mixture of uncertainties, statistics is presented like an enigma to the students of engineering, especially if statistics is taught in the early stages of their program. This happens in Argentina where the roles of statistics in engineering are very difficult to demonstrate because students have only taken basic subjects like mathematics, physics or biology.

INTRODUCTION

Today's probability and statistics are in most engineering curricula in many countries. Nobody doubts nowadays that all professionals should be qualified to design an investigation, gather data with previous planning and analyze the results (Fernández de Carrera, 2002).

If the needs of themes related to statistics within the engineering careers are analyzed considering the advancement of the professional's future career, none of their content would be inappropriate. Data analyses, experimental design, risk / survival analyses and theoretical concepts like stochastic processes are necessary in solving more than one current engineering problem, and in certain cases, some of them are needed to a greater extent according to the specialty.

The importance of using statistics to measure the product variability in each area of engineering has been extensively discussed. To continue competing in different markets, the industry should improve the product and service quality. The effort in this improvement should be done by engineers and scientists as well given the fact that they are the ones involved in the design to develop new products and to improve the ones already existing.

Education is one of the major worries in the societies of the First World countries. It is said that Argentina is also worried about this situation even though the low Gross National Product percent investment in Education seems to deny this affirmation.

The speed knowledge is growing nowadays makes the information that had been previously acquired be scarce and obsolete. Therefore, this dynamic requires a permanent updating. Statistics is considered not only one of the fundamental methodological sciences but also the basis of the experimental scientific method, helping the student's personal growing and encouraging their critical reasoning based in giving importance to the objective evidence (Batanero, 2002). Furthermore it is important to emphasize the need to "think statistically" and to further its studies, adding the statistical science contents to the core curricula of the different engineering areas (Davies, 2001). Even if the still to be discussed Parry-Jones (1999), cited by Davies (2001), innovative and radical way of teaching statistics is adopted, there still exists a question to be clarified "*Is it necessary to teach the same program in all the engineering areas? Do the engineering fields like the ones involved in design, or the others related with electricity and electronics, including mechanical engineering, civil and even the biological ones need the same knowledge?* For example, are stochastic processes and all the theoretical side of the theory of probabilities, like combined distributions, moments, distributions of the addition and other properties, really needed in all the specialties?

To reach the objective mentioned, a course on theory of the probabilities is very much needed. Thus, another question arises, is it necessary to include all the Methodology of Statistics? Though the idea of what a basic course in statistics should be depends basically on the professor

in charge of the subject, I agree with Montgomery and Runger (1996) on the fact that a first level course on statistics for engineers should be principally a course on Applied Statistics, and not a course on Theory of Probabilities and its applications. Many years of experience and thinking about questions, plus the fact that as time goes by they become more and more complex given the rapid growth of knowledge, lead me to share these reflections.

The objective of this paper is precisely to bring into consideration the still unsolved problem - mainly in Argentina, my country- related to what the course contents are, up to what extensions they should be developed and whether these contents are to be included in the core curricula? I believe that this is the appropriate moment to make the change. The Ministry of Education's authorities have created a National Master Program involving all the different State Schools/Faculties of Engineering. The "Program for the Improvement of the Teaching Process in Engineering" (PROMEI, in Spanish) has to do with the necessary modifications to improve the careers of Engineering in all the specialties. This Program is based on the fact that when evaluating the careers/professional skills/abilities/quality, the results were not quite satisfactory.

ENGINEERING CORE CURRICULA

Much of the recent discussion about the contents of the first course in Statistics was related to considering Statistics as a discipline, with emphasis on problem-solving skills and teaching and learning one form of viewing the reality, with a particular emphasis in interdisciplinary work.

In general, the accreditation processes of engineering studies need to assess not only their graduates' but also their professors' qualities/skills/abilities. Yet, it is necessary to state in detail what those qualities-skills/abilities are.

Dansie (2005) says that the University of South Australia states that its graduates will have the ability to work with and upon a body of knowledge, to engage in lifelong learning, to be effective problem solvers and communicators, to work autonomously and collaboratively, to be committed to ethical action and social responsibility and to demonstrate international perspective.

I believe these to be the minimum abilities/skills qualities each university's graduate from a school of engineering should have, plus those specific skills each Institution considers necessary to add in order for a student to be granted a degree.

In the core curriculum design, the graduate's qualities like Institutional values play an important role too. Furthermore, each different engineering field, like bioengineering, biotechnology, food engineering, needs not only a basic course in statistics but also one in learning experimental design, one/two way analysis of variance, parametric or non parametric methods, multivariate analysis, general linear models, procedures among other subjects in order to fulfill the graduates' minimum requirements in these specific specialties when having to face their future profession.

Stochastic Processes and Theory of Probability are areas that should not be left aside in different engineering fields such as Electronics in Communicational Engineering, or in those fields that have to do with Informatics or Computer Technology. These are not only necessary to further develop as professionals but also to understand more advanced subjects in the career of the student's choice.

CREDIT HOUR REQUIREMENTS

Currently there is an undergoing research on the contents of Mathematics throughout all the State Schools/Faculties where some of the many different areas of engineering are taught so as to analyze their similarities and differences. In almost all of them there appears to be only one course in Probability and Statistics is taught, yet in some Schools, mainly in those where the engineering is related to Electronics, Communications or Computation, this elemental course is followed by another on Probability and Stochastic Processes. However, in some Schools/Faculties both courses combine to form only one. In 80% of the cases the credit hour requirement assigned to those courses results in approximately 70 to 80 class hours in the semester. This gives rise to the question: Is it possible to achieve anything in that short time? Evidently, before this question, it is necessary to find an answer to Which are the abilities, skills and knowledge the student had before beginning high studies?

I also agree with MacGuillivray (2001) regarding the concept that in Argentina also "*the school scene is generally characterized by the acknowledgement of the importance of 'Chance and Data' but also by the significant absence of knowhow and resources to support this, and sometimes even to identify what could or should be done.*"

PREVIOUS CONDITIONS

The past decade has seen a serious decline in students´ basic mathematical skills and level of preparation on entry into higher education, thus causing many students to embark on engineering degree programs without the necessary maths skills required for the course.

During 1994, in Argentina, a reform in the educational system was produced. Primary and secondary traditional teaching was modified into Basic General Teaching (EGB, in Spanish) and Polimodal Education. Attending school is mandatory until finishing the third stage of Basic General Teaching (EGB 3), being 14 years of age on average It is no longer mandatory for students to attend the Polimodal stage. It is considered that these mathematical problems have increased and worsened and it is also understood that they have arisen from a number of factors including:

- Widening of access to higher education – resulting in the acceptance of students with much more diverse backgrounds and experiences of mathematics than previously.
- Inadequate mathematics preparation in pre-18 education- due to a variety of causes including curriculum shortcomings, not enough emphasis on assessment and shortage of mathematically qualified teachers, and social influences.

Unfortunately, this situation is worse with regard to the Statistical Sciences.

From this reform onwards, contents involved with data management (frequency counting), and graphics interpretation (bars, pies and pictograms charts) were introduced from the first EGB cycle to Polimodal Education level where Probability as well as Distribution Probability are to be completed. "Stochastic thinking" has arrived at all levels of the educational curricula. Twelve years have elapsed during which there existed the possibility of incorporating these subjects and confronting students with the concept of uncertainty so frequent to all citizens that even all forms of communication use it. So the question arises Does the school prepare him/her to do it? This happens not only in Argentina but also in many countries around the world, where education has to meet this challenge in the last years. The need for mathematically literate students who can function in today's technological society has promoted a change in the content of the mathematics core curriculum (Starkings, 1997; Fernández de Carrera, 2002).

This may be due to diverse causes, among them the lack of concise and clear concepts, or maybe to deficiencies in their careers, or it could be that these concepts had not been taught before or had been forgotten. In general teachers, like students, acquire some of their statistical background from informal sources. Statistics teachers often lack adequate foundation in this science or perhaps they may even lack the adequate training to teach it.

Results obtained show that students come to the first university courses on Statistics and Probability with almost no systematic knowledge of probability elemental concepts. Though they have developed intuition, making use of it sometimes, we infer that middle school teaching does not prepare them to face several problems concerning these concepts and specially the one referring to uncertainty (Fernández de Carrera, 2002).

THE NEED TO WORK ON PROBLEM SOLVING

The teaching of Statistics does not have its own theory. Consequently, it is suggested to interpret it from the point of view of those sciences/subjects that belong to mathematics education and that do have developed theories. (Garfield, 1995; Ottaviani, 1999; Batanero, 2001). The theories on the education of mathematics are based on those epistemological positions that consider it as a construction of the human being, tending to satisfy his/her needs and to solve problems in different areas, including those related to every day life. Consequently, the problems and their solutions are presented like the very best situation in the task of teaching statistics. The resolution of problems is adapted from the constructivist approach as a theory of learning, helping the student in the solving of the proposed problems. While searching for the solution, the

participants need to expand their knowledge, analyze a particular situation, design an experience, collect data, verify their hypothesis and generalize their results.

The acquisition of the "statistical thought" or "statistical reasoning" we are proposing has recently been conceived. Consequently, this position and asking oneself *What is the statistical thought?* has resulted in recent research like the one from Wild and Pfannkuch (1999) that distinguished five fundamental components in this reasoning: to acknowledge the need of data (quantify), what evolves from these data (exploratory analysis), to perceive the variation or variability, to find a model and to integrate the statistics to the context of the problem. Each one of these five components is important, yet the first three are the foundation that each citizen should have and that anyone who has a position that involves a decision making situation in the society should know unless he or she is unable to exercise his/her obligations. Therefore, to learn statistics is not to learn how to make numbers or to acquire one more outstanding capacity to use statistical software. Nowadays, its easy access leads to its indiscriminate use without considering all its potential and the needed requirements to know how to use a specific test. Consequently, there has been a spontaneous appearance of a number of "experts," without any statistical formation who dare to reach a conclusion just because they are skilful in working with specific software, making inferences without any theoretical support.

Computing technology has expanded its possibility and learners and teachers have greater accessibility to it. It is mandatory to integrate the PC to the class of statistics using demonstrations and visualizations, to enhance both skill and conceptual development. Evidently there is a before and after in the teaching of this subject directly related with the presence of the Personal Computer. Due to its presence, it is possible in our classes to allow the student to acquire ways of thinking with less time in tedious calculations - a situation that would be difficult to overcome without the presence of the informatics technology.

In our Institutions, the first courses in statistics will focus on developing the statistical thinking, problem solving and the probability as a way to measure uncertainty. What is more, in our courses we show the students the way they could use statistics to solve problems related to engineering or to technology. To do so it is necessary to include real problems that are to be taken from specific publications or that are real facts that have to be processed and were presented by professors from other subjects in the career. All this process requires the ability to integrate a range of skills, knowledge and attitudes into strategies to overcome this complex situation.

CONCLUSION

There are too many questions, many of them with various answers. Probably, from their discussion it is possible to reach a solution. It is my opinion that with the credit hour requirement, a basic course in Methodological Statistics is top priority. Furthermore, a course in Theory of Probabilities and Stochastic Processes and their applications are also important to be included as a part of continuing education courses or courses in parallel to the core curriculum of the different engineering or technological careers that need them. It is also important to offer a second course oriented to the different engineering fields in order to provide the future professionals with a minimum knowledge on Statistics science. This should allow them to become a skilful and intelligent user of the statistics, to be part of interdisciplinary teams with other professionals, among them statisticians, with the objective of solving the complex problems that have to do with today's reality.

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