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DEVELOPMENTS AND PERSPECTIVES IN STATISTICAL EDUCATION

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ABSTRACT

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The promotion of education in any scientific field implies paying attention to a delicate aspect: the contact of the specialists in that science with the wider society. In this perspective statistical education (interpreted in the broadest sense possible) favours and promotes the understanding of the basic concepts of statistics in society at large, as well as in other discipline areas and /or in other professional bodies. This obviously contributes to give statistics more visibility. In order to further the improvement of statistical education at all levels and in all contexts, the International Statistical Institute (ISI) favoured the establishment in 1949 of the Committee on Statistical Education which ceased to exist in 1991 when the International Association for Statistical Education (IASE) was founded. Little by little a world-wide professional community involved in statistical education grew. Through research in statistical education, statistics has proved to be a “modern discipline” useful for developing most of the skills required by the global world and the information society. Among the abilities needed in today’s society are skills required for collecting, organising and analysing data, working with others in groups, using technology and applying a problem-solving approach. Currently not all statisticians are aware of the full potential of their discipline and one of the roles of the IASE is to promote statistical education in order that all statisticians may become familiar with the full potential of statistics.

KEY WORDS: Teaching/learning statistics; Research in statistics education

1. INTRODUCTION

The world in which we live is rapidly becoming like a “global village” as it is closely connected by modern telecommunications and interdependent economically, socially and politically. In this new world it is important to be able to orient oneself in a web of available information, much of which is quantitative. As a result the modern citizen requires new skills. He or she must, for example, move within masses of quantitative data which may at times be contradictory and which require of him or her a minimum awareness of how such data is collected, organised, analysed and interpreted.

The citizen must know the conventions, which permit him or her to judge the quality of quantitative information divulged by the media. He or she must be able to use the quantitative data to control the expression of his or her own, and others’, opinions and must be aware of how quantitative information can be of use in problem solving and in choosing from a variety of possible solutions.

Statistics is capable of supplying these cultural and practical needs. In fact it concerns itself with the quantitative study of collective phenomena, whether they be economic, demographic, social, or of an experimental nature. Particularly, statistics attempts to explain the variability inherent in all phenomena, which is the diachronic and synchronic tendency to change which is present in the real world.

Therefore the study of Statistics is necessary for the citizen to fully develop his or her capacity to orient him or her self in his or her world, and not solely as a technique, but as a way of thinking which, having become the required means to obtaining a quantitative awareness of socio-economic phenomena, is consequently necessary in order to allow a complete democracy to exist.

2. THE IMPORTANCE OF STATISTICAL LITERACY FOR CITIZENS

This is so highly recognised at international level, that UNESCO implements policies for development, both socio-economic and cultural, for all the Nations which include not only literacy but also numeracy. This being the case, statisticians feel the necessity for the diffusion of Statistics, not only as a technique for dealing with quantitative data, but also as a culture, in terms of capacity to comprehend logical abstraction, which makes possible the quantitative study of collective phenomena. Statistics is concerned with complex study which, starting from a definition of the object under examination, and thus a definition of whatever one seeks to measure, passes through data collection, its representation and analysis in order to reach the extremely delicate phase of interpreting and commenting, which renders explicit the knowledge of the phenomenon which has been studied.

Facing the problem of the statistical culture and its diffusion is therefore much more than concerning oneself with training a few specialists, it means, in fact, for statisticians, relating to the general know-how possessed by the average person at present, in order to allow him to fulfil the needs of an information-based society, towards which we are progressing rapidly. Discussing the diffusion of the culture of statistics, requires a mid – to long term perspective. Such time is necessary for people to be trained in statistics in schools, it is necessary for people to understand that statistics is linked to a way of reasoning which allows the acquisition of knowledge through experiments and/or observations; time is necessary because people learn to value technical awareness and even more so acquired logic, so that quantitative information can be consciously used, whether collected by oneself or provided by external sources.

The aim is to train citizens who are able to evaluate statistical data critically, also that from official sources, since he or she is conscious of the procedures by which the data is obtained, knowing that even the best statistical data is only the representation of a part of reality: that which has been observed. He or she is aware that the data available is merely an image of reality and not true reality itself, which humankind will not be able to take hold of, even through statistics.

The critical focus towards data must be counterbalanced by the awareness of the usefulness of the information required concerning the reality under examination, whether it be for a merely cognitive aim, or a decision –making one. In other words the statisticians must have to succeed in making the usefulness of statistics evident, and above all its way of reasoning understood.

3. THE ACTIVITY OF THE ISI TO PROMOTE STATISTICAL EDUCATION

In order to further the improvements of statistical education at all levels, and in all contexts, the International Statistical Institute (ISI) favoured the establishment of the International Association for Statistical Education (IASE) in 1991. The birth of the IASE was the end of a long move initiated in 1949, immediately following the Second World War, with the founding of the Committee on Statistical Education within the ISI, through which the Institute itself promoted the university training of Statisticians at international level, while in developing countries the ISI concerned itself with the education of official statisticians (Rice, 1949; Gani, 1979; Vere-Jones, 1995). The ISI had begun paying more attention to teaching statistics in schools since the mid seventies. In those years, mainly in developed countries, socio-economic conditions improved, quantitative information given by governments and published in newspapers was ever more frequent, and personal computers became ever more widespread. Moreover the teaching of Mathematics in schools began to change, so that also statistics and probability could find a place within the mathematics programme in pre-university schools, and statisticians became conscious of the necessity to go deeper into the teaching/learning problems that teachers of mathematics had to face when dealing with teaching statistics in schools.

In 1976, the ISI re-emphasised its propositions for statistics teaching (Zarkovich, 1976). Knowing that the theme of teaching could offer the best possibility of influencing the future development of statistics, the ISI underlined the necessity to:

- produce comprehensible university textbooks with applications connected to “real life”;
- encourage the definition of high school and university programmes, above all those of new institutions;
- publish a Journal to assist teachers at different levels in terms of keeping them informed;
- organise general meetings, for those interested in the teaching of Statistics, different from those formal ISI Round Tables organised up to that point for experts in statistical education.

From 1979-1987, the Education Committee, chaired by Professor Gani, succeeded in obtaining important results, through the creation of diverse “Taskforces”. Thanks to these, but also thanks to the willingness and involvement of those in charge of each taskforce, significant initiatives were taken. In 1979, at the International Centre for Statistical Education at Sheffield University, “Teaching Statistics” was first published, one of the most important didactic statistical Journals distributed in secondary schools, colleges and universities all over the world. Furthermore the International Conferences on Teaching Statistics (ICOTS), the first of which was held in Sheffield in 1982, were initiated and they continue once every four

years. The International Statistical Education Newsletter (ISEN) began to be published in order to inform ISI members of the Committee's work, and to keep them up – to- date as regards teaching statistics and its problems.

The publication of "Teaching Statistics" and its distribution, and the success of the ICOTS demonstrated that statistics teachers felt a strong need to unite, talk, and discuss the problems experienced in the course of their daily activities. In the meantime, it gave specialists in epistemology, psychology and statistical education the possibility to expound the results of their research and theories. At the beginning of the 1990s, it became clear that there existed forces and energy for the creation of an International Association for Statistical Education. These forces became recognised in the course of the ICOTS and would have emerged even without the leadership of the ISI. Consequently, at the Cairo Conference in 1991 the proposal to establish an International Association for Statistical Education as a new Section of the ISI was approved by a unanimous vote of the ISI General Assembly. With the establishment of the IASE and the transfer of statistical education activities to it, the Education Committee ceased to function as such.

4. THE IASE AND THE ADVANCEMENT OF STATISTICAL EDUCATION AND RELATED RESEARCH

According to the Statutes for the IASE: "The objectives of the Association shall be to promote the understanding and advancement of statistical education and related subjects and to foster the development of effective and efficient educational services through international contacts, among individuals and organisations including statistical educators and educational institutions". To fulfil these aims the IASE was expected to develop a publications programme as well as to continue with the program of ICOTS and Round Table Conferences and statistical education sessions at more general meetings. Besides this it was envisaged that a number of committees and working groups would be formed to address specific areas of common interest.

Thanks to a Transitional Committee, in charge from 1991 to 1993 and chaired by D. Vere-Jones, the first election of IASE Officers was prepared as well as the first General Assembly that was held in Florence (Italy) on August 27, 1993. Since then the IASE has had three elected Executive Committees. The first was chaired by D. Moore, USA, (1993-95), the second by A. Hawkins, U.K., (1995-97), the third by M. G. Ottaviani, Italy, (since 1997).

As a professional association for people with a strong interest in statistical education, the IASE includes both those who conduct research on teaching and learning and those who develop materials and teach at all levels from schools to specialist training. The community of teachers, educators, researchers forming the IASE memberships has allowed the Association to bring many initiatives to a successful conclusion.

Other meetings have been added to the traditional ones. In 1993 the First IASE Scientific Meeting was held in Perugia (Italy) as a satellite to ISI Florence. The papers published in the Proceedings covered – in addition to classroom and curriculum problems in schools and universities – such topics as: the training of government statisticians, the use of videos, training in consultancy, electronic communication as a tool, and statistical education in developing countries. In 1994 the Second IASE Scientific Meeting took place in Cairo, in Arabic, discussing the teaching of statistics problems at pre-university level, as well as teaching mathematical statistics and probability, teaching statistics for students of basic and experimental sciences and teaching statistics for students of humanities at the university level. The Proceedings were published in the Arabic language.

The IASE has a collection of books on statistical education that carry its logo. The most recent additions are: *Papers on Statistical Education presented at ICME 8* (1996) edited by B. Phillips to collect statistical education issues covered by the IASE at the 8th International Conference on Mathematical Education (ICME); the *Proceedings of Tartu Conference on Computational Statistics and Statistical education* (1996) reflecting a statistically representative sample of the problems discussed at this IASE/IASC Conference; the volume on *The Assessment Challenge in Statistics Education* (1997), edited by I. Gal and J. Garfield, a book discussing conceptual and pragmatic issues in the assessment of statistical knowledge.

Sessions on statistical education have been organised by the IASE at the general 50th and 51st ISI Sessions held respectively in Beijing, 1995, and in Istanbul, 1997.

The IASE has continued to sponsor Roundtable Conferences on specific topics as satellites to the quadrennial ICME meetings. In 1992 the IASE Round Table was held in Lennoxville, Quebec, Canada dealing with the topic: *Introducing Data Analysis in the Schools: Who Should Teach it and How?*. The proceedings, edited by L. Pereira Mendoza, provide a broad perspective of differing issues associated with statistical education with a particular emphasis on data analysis. In 1996 the IASE Round table was held in Granada, Spain, on the theme: *Research on the Role of Technology in Teaching and Learning Statistics*. The proceedings, edited by J. Garfield and G. Burrill, develop a wide range of interest and expertise on a theme provoking a widespread international debate on a topical issue facing statistical educators.

No doubt, however, the International Conferences on Teaching Statistics (ICOTS) are the most important means of interchange that the IASE offers to the community of professionals and researchers concerned with statistical education. The ICOTS meetings are notable as a venue for discussing statistical education with people of the most varied backgrounds. In 1994, ICOTS 4 was held in Marrakech, Morocco, sponsored by the ISI and the National Institute of Statistics and Applied Economics of Morocco. The proceedings included topics ranging from the statistical literacy of citizens, through the teaching of statistics to various specialised groups - such as economists, engineers, official statisticians, social scientists -, to data analysis for the elementary curriculum. In addition, several work groups sessions were held which provided the opportunity for in-depth discussion of certain specialised topics; one in particular was devoted to the "Activities of Professional Societies in Education and Public Awareness of Statistics".

5. RESEARCH IN STATISTICS EDUCATION AND THE "MODERNITY" OF STATISTICS AS A DISCIPLINE

5.1 Introduction

Little by little a world-wide community involved in statistical education has doubtless grown. This has been made evident by the activities of the IASE members. They have formed two specific Study Groups with the objective of connecting people interested in different areas. The International Study Group for Research on Learning Probability and Statistics was started in ICOTS I (1982) in order to encourage research in statistical education; promote the exchange of information between members; develop instruments by which concepts about probability and statistics could be assessed; and in general improve the teaching and interpretation of probability and statistics by dissemination of research findings. There have been three secretaries of the group: D. Green (1986-88); J. Garfield (1988-96) and C. Batanero (since 1996). More recently, in 1994, the Psychology of Mathematics Education (PME) Stochastics Teaching and Learning Group was established as a discussion group. In 1997, it changed into a working group with the goal of linking two research areas: studies concerned mainly with psychological aspects of stochastics learning, particularly decision-making in an uncertain environment; and studies concerned mainly with pedagogical aspects of stochastics education. As it is planning a new handbook on statistical education from a research perspective, its structure is changing now into a project group. During ICOTS 5 a network system was launched connecting together people who share their professional interests. Six new lists have been proposed and four of them have already started as email lists.

Through research in statistical education, statistics has proved to be a "modern discipline" useful for developing precisely those skills required by the global world and the information society. Among the abilities needed in today's society are, in fact, applying a problem-solving approach, using technology, developing the skills required for collecting, organising and analysing quantitative data, and working with others in groups. All these skills may be acquired thanks to statistics teaching.

5.2 Teaching Statistics and "problem solving"

In fact, research into statistical didactics has clearly shown that statistics is particularly adapted to that theory of learning which is known as “Constructivism”. This theory stems from the work of Piaget and his collaborators and has been widely accepted within mathematics education.

“Constructivists view students as bringing to the classroom their own ideas. Rather than receiving material in class as it is given, students restructure the new information to fit into their own cognitive frameworks.” (Garfield, 1995, pages 25-26). In this context the teachers’ task is essentially to provide opportunities for students to actively construct knowledge, acting as a coach, a moderator, a consultant who presents the material, solicits opinions and responses from the class, rather than someone who has to transmit a designated topic.

The fundamental strategy in constructivist theory is problem-solving. Problem-solving consists of encouraging the student to solve a problem and to widen his/her knowledge through the analysis of a particular situation, the formulation of a project, by gathering information, interpreting the data, verifying the hypothesis and generalising about the results. Statisticians know that statistics is an ideal platform for this kind of approach. It could be said that the pedagogical advantage of starting by posing a problem provides a context for statistical concepts, and solicits queries to be solved by statistical analysis and statistical thinking.

With regard to “Constructivism” statistics no doubt enjoys a privileged position. Working with data, forming dialogues with this, and interacting with those areas of application which the data refer to, is in fact the statistician’s habit of mind.

5.3 Teaching statistics and the computer

In statistics particular attention must also be paid to the special relationship between this discipline and the computer. The computer has been used in statistics since the 1960’s. What the statisticians were mainly dealing with, however, were mainframe computers, tools for specialists which were by no means easy to use. This changed with the introduction of the PC during the mid-1980’s, which permitted this technology to be widely applied in both a simple and user-friendly manner.

The computer has been and continues to be fundamental for research concerning statistical method. Nor can statisticians themselves do without the computer when applying methodology to the quantitative study of collective phenomena, irrespective of the substantive discipline statistics is applied to. Be it on account of the size of data sets dealt with, or the complexity statistical techniques have now reached, statistics can no longer be done “by hand”.

The computer is therefore indispensable for research but it is also important in the teaching of statistics. Here it is to be seen not merely as a tool for calculation, but rather as a means of acquiring concepts, of understanding these better and of knowing their theoretical and practical implications. To grasp the extent to which the computer can assist in the process of teaching learning/theory, we should consider the advantages of dynamic graphics in understanding regression or displaying outliers and/or influential data, not to mention how the computer facilitates the performance of simulations of theoretical distribution and their mixture and, simply, how it assists in our understanding of the mechanisms of variability. With regard to the process of teaching/learning the logic of statistics and subsequent aspects of applications, the attempt should be made to encourage the student to grasp the entire cognitive process of real phenomena, and start by collecting real data, go on creating the corresponding data set, preparing it for the analysis, producing the output results for the report, concluding with the crucial phase of interpreting the results obtained.

Furthermore a technological environment allows statistics teachers to utilise other didactic strategies such as: modelling and simulation. Modelling and simulation by computer generally comprise the construction of one or more abstract models to explain a real situation, by studying these through controlled variations of the parameters, and by identifying how opportune these are to interpret reality. For statisticians simulation is fundamental and plays the same role the laboratory plays in science: a mine of experiences! Statistics teachers can use simulation to illustrate principles and techniques, to show the heuristic potential of methods and mechanisms, and to have the student undergo certain experiences in a controlled

environment.

Introducing Statistics into teaching becomes useful also for the acquisition of a greater familiarity with this technological instrument, whose importance can be shown in order to deal with data of different origin, this topic emerging also in that field of Statistical research named “data mining”.

5.4 Some reflections on teaching/learning statistics

Working with data is a fundamental approach to constructing knowledge, as well as being the basis for statistical analysis, thus becoming an important discipline from the point of view of education and teaching. Statistics, which by its very nature is multidisciplinary and privileges the dialogue with data, facilitates teamwork among experts from various sectors and is therefore ideal for the use of multimedia instruments. Of particular importance in the success of this kind of teaching is the choice of data made by the teacher for the students’ use, which should promote group discussion and favour the introduction of important statistical concepts. The preparation of suitable material, also capable of encouraging class interaction, is much more time consuming than a good, standard in-class lesson. However, perhaps this is a challenge which is worth confronting in teaching/learning statistics.

Hermann’s theory of the four thinking processes demonstrates that different learning approaches call for different learning methods. The topic we teach can satisfy each of these. It is suitable for those who are *logic based* - who like a formalist treatment of mathematical statistics -, *intuitive* – those who are keen to explore the data and thus opt for applied statistics -, ordered *planners*, who learn from formal lessons, clear summary-type layouts, and drills, an approach practised today particularly for university teaching of advanced statistics -, and *feeling based* – those students who like to discuss the data, devise common projects and share experiences, an approach which is favoured by young people and is thus suitable for teaching statistics at a pre-university level and/or for introductory university courses.

6. A LOOK AT THE FUTURE OF STATISTICAL EDUCATION THROUGH THE ISSUES OF ICOTS 5: A PERSONAL VIEW

The IASE is now seven years old and last June, in Singapore, the Association organised the fifth International Conference on Teaching Statistics, with the participation of about 300 delegates from all over the world. Meeting together is always a moment of great pleasure and interest for all statisticians who work in the field of Statistical education. Usually, in fact, they perform their activities quite alone within a department of statistics or mathematics and statistics or educational sciences, so that consequently they are afraid of having isolated opinions and interests which are not commonly shared by others. The statistical community should consider that the promotion of education in any scientific field implies paying attention to a delicate aspect: the contact of the specialists in that science with the wider society. In this perspective statistical education (interpreted in the broadest possible sense) favours and promotes the understanding of the fundamental concepts of statistics in society at large, as well as in other discipline areas and /or in other professional bodies. This obviously contributes to give statistics more visibility.

Currently not all statisticians are aware of the full potential of their discipline and one of the roles of the IASE is to promote statistical education so that all colleagues may become familiar with the full potential of statistics. This requires also that the IASE promotes the diffusion of the different activities that the Association has organised and is going to organise first of all by contacts within the ISI family that is to say with the Bernoulli Society, the IAOS, the IASC, the IASS and the ISI itself.

The materials presented at the fifth ICOTS from June 21 to June 26, 1998, contributed to strengthening how important the teaching of statistics is from didactic and pedagogic viewpoints, for furthering those individuals skills needed in a modern society. All of which is the result of ever more intent and deeper studies and research in the field of statistical education.

But there was also another equally significant contribution. Among the keynotes, two papers were presented at ICOTS 5 by professional statisticians: Paul Cheung, Chief Statistician, Singapore, discussed “Developments in Official Statistics and Challenges for Statistical Education” and Roger Luk, Managing Director and Deputy Chief Executive, Hang Seng Bank, Hong Kong, PRC, talked about “Application of Statistics in the Business World”. Both of them showed the need for quantitative information and its ever wider use by governments and in economics, and each in a different way illustrated that “Like any science subject, the theory of statistics is meant for a perfect or ideal world, which hardly exists in reality”, and so when applied to reality the consciousness of the phenomenon under examination is needed to help the user in bridging the gap between theory and practice.

In this way two key issues emerge from the concerns of the Conference:

- the demand for recognition in academic world that research in statistics education is a research discipline in its own right;
- the problems in statistics training of those researchers and professionals who must then apply statistics to diverse substantive disciplines.

The first problem may be solved when the community of statisticians will make clear the awareness that the researchers in statistical education have their own particular and important role. As statisticians, they investigate statistical education, using statistics as an instrument with which they can contribute at the same time to the development of theory and application of the discipline. As scholars of the science of education, they permit the deepening of logical processes of teaching/learning of statistics. In doing this they very often use statistical methods in a refined manner and are therefore researchers who appreciate the usefulness of the statistical methods and favour their diffusion at the research level in the education science field.

As regards the problem of the training of those, researchers and professionals, who have to use statistics, one of the biggest challenges to face is to avoid the risk of “fragmentation of the subject” feared, among others, by such illustrious statisticians as Cox (see Cox, 1997, p.262). Perhaps statistics needs to be better characterised, making evident its peculiarity which consists of the quantitative study of real phenomena. In such a way it might be possible to recover the entire process of scientific investigation from the design, through data collection and data analysis to the interpretation of the investigated phenomenon, without limiting oneself solely to the phase of data analysis, as some statisticians are used to thinking to day. Possibly an attentive, patient work of reconstructing history, logic, philosophy, and epistemology of statistics could help to attain this fundamental goal. But this could also be the way to find those “general principles of statistics” (Cox, 1997, p. 261) that apply to experiments as well as to observational studies. To single out these general common principles should favour “a teaching approach that could be relevant and accessible to both specialists and non specialists. (Keeping in mind that) An understanding of general principles gives flexibility and transferable skills” (Hawkins, 1997, p.281). Finding these “general principles” should also help in “ Bridging the gaps among School, College, and the Workplace”, as R. Schaeffer titled his brilliant keynote discussed at ICOTS 5. In giving an articulated perspective about the way to bridge the gaps among statistical education and training aspects on one hand, and the statistical needs in the society and particularly in the workplace on the other, Schaeffer concludes: "The process of building a solid core of statistics into the school and college curriculum is one of infusion for the many and specialisation for the few". No doubt to plan this particular building is a fundamental challenge the statisticians have to face in the immediate future. The IASE is fully aware of the importance of the subject and will confront, in a systematic and articulate way, the

theme of training researchers at the next Round Table on the theme: "Training Researchers in the use of statistics", to be held in Japan in the year 2000.

7. CONCLUSION

The activity and research of the IASE and its members give rise to results that are important not only to the Association itself and its membership, but also to the community of the statisticians.

As C. Jarque, the President of the INEGI noticed in his keynote address at this joint IASS/IAOS Conference "we all share a planet full of significant and accelerating ecological, demographic, economic and scientific transformations that reach into every corner of life." "In summary, the environmental, demographic, economic and scientific transformations constitute clear trends which require priority attention by the world community at the end of this millennium. In particular, they already have an enormous impact on the demand of statistical data, on statistical methodology, and on national and global statistical systems." (Jarque, 1998, p.8, pp 19-20).

The statisticians cannot but agree with C. Jarque. They have to consider, however, that to have "good" statistical data requires "good" statisticians who can dominate the entire process of scientific investigation and can plan design, collect and analyse data, interpret them, but it is also necessary to have citizens conscious of the importance of data collection and surveys as well as of the utilisation and interpretation of data.

All of this requires the promotion of Statistical Education at all levels, and this is the IASE's objective.

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