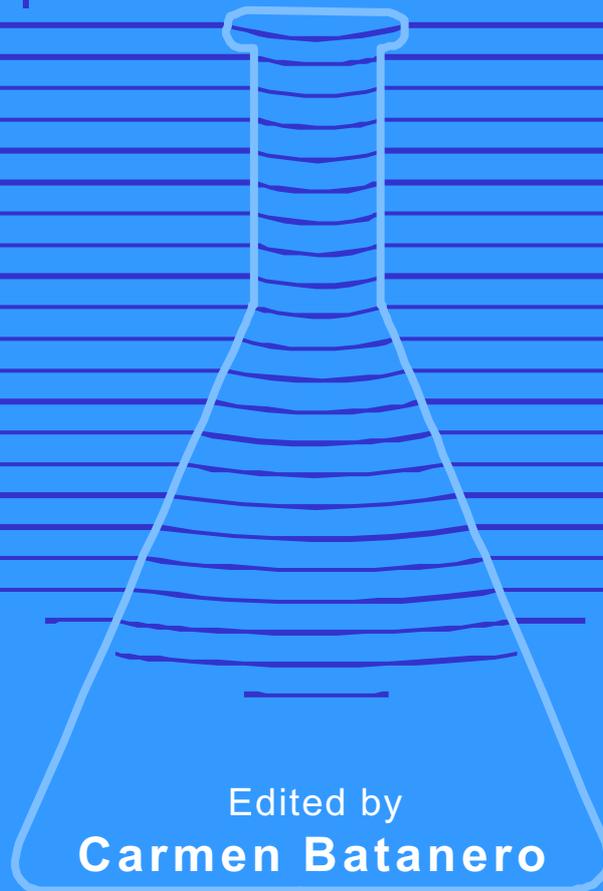


# Training Researchers in the Use of Statistics

**IASE Round Table Conference**

**TOKYO 2000**



**International Association  
for Statistical Education**



**International  
Statistical Institute**

# Training Researchers in the Use of Statistics

IASE Round Table Conference, Tokyo 2000



# Training Researchers in the Use of Statistics

Edited by:

Carmen Batanero

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International Association  
for Statistical Education



International  
Statistical Institute

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## FOREWORD

There is no doubt that the training of researchers in the use of statistics is very important to improve the quality of empirical research and to foster technical and economical development. Empirical sciences, in general, rely heavily on the statistical analysis of data, in particular on inferential statistics. However, since the logic of statistical inference is difficult to grasp, its use and interpretation are not always adequate and have been criticised for nearly 50 years.

Books, such as the classical work by Morrison and Henkel, *The Statistical Tests Controversy* published in 1970 by Aldine or the more recent book by Harlow, Mulaik and Steiger, *What if There Were No Significance Tests?*, published in 1997 by Erlbaum, and a wide related literature suggest that scientists often apply statistics in a mechanical way, that they are paying too much attention to the significance tests' results and are forgetting other statistical methods, as well as the estimation of the magnitudes of the effects they are investigating.

Given the increasing complexity and new methods emerging in the field of statistics, it is difficult for researchers to bring themselves up-to date in the new statistical procedures and, therefore, there is a clearly increasing need for the statistician's support in empirical research. However, in many cases, the statistician is only consulted after the data has already been collected, with the inherent consequences of poor experimental design, biased sampling methods or inadequate data. The ready accessibility of statistical computer programs may even provide an excuse for not consulting a statistician at all in some cases, to the subsequent detriment of the scientific quality of the research.

The controversy about the adequate use of statistics has recently increased within professional organisations such as the American Educational Research Association or the American Psychological Association, which are suggesting important shifts in their editorial policies regarding the use of statistics and are recommending better use of statistical language in reported research. Research journals in medicine such as the *British Medical Journal* or *Statistics in Medicine* have highlighted the poor quality of methodology and statistics in medical research. This debate is also reflected in research journals in psychology, and education (e.g., in *Educational Researcher*, *Mathematics Education Research Journal*, *Theory and Psychology*, *Educational and Psychological Measurement* or *Educational Psychological Review*).

Some explanations suggested in these debates for the persistence of an inadequate or inappropriate use of statistics include inertia, conceptual confusion, lack of better alternative tools, and psychological mechanisms such as invalid generalisation from deductive logic to inference under uncertainty.

Within the International Association for Statistical Education it was felt that there was an educational problem at the root of this dilemma and that the training of researchers should be analysed by statistics educators from its various perspectives and approaches. As a result a *Round Table Conference on The Training of Researchers in the Use of Statistics* was organised at the Institute of Statistical Mathematics in Tokyo, August 7-11, 2000, where researchers from around the world met to discuss the topic and to produce suggestions about possible ways in which statistical education might contribute to the

better understanding and application of statistics in applied research. This conference on the training of researchers also served to illustrate the need to understand statistical concepts and to develop statistical thinking at all educational levels.

The present book includes the works and discussions at the Conference and it is one of a series of publications resulting from the International Statistical Institute and International Association for Statistical Education Round Table Conferences. The first Round Table Conference was organised by the *ISI Education Committee* in 1968 in The Hague on the theme “The University Teaching of Statistics in Developing Countries”. Subsequent ISI Round Table Conferences dealt with “New Technologies in Teaching Statistics” (Oisterwijk, The Netherlands, 1970), “Statistics at the School Level”, (Vienna, 1973), “The Teaching of Statistics in Schools” (Warsaw, 1975), “Teaching of Statistics in the Computer Age” (Canberra, 1984), “Training Teachers to Teach Statistics” (Budapest, 1988), and “Teaching Data Analysis in Schools. Who should Teach it and How?” (Quebec, 1992). The first IASE Round Table Conference was organised in 1996 in Granada, Spain on “Research on the Role of Technology on Research in Statistics Education” and it is planned to continue this series of conferences focusing in new educational topics every four years.

The Tokyo conference was not an isolated event, but a part of a long international collaborative process, which started in 1997, when the IASE Executive Committee decided the topic for this particular Round Table Conference and later nominated Carmen Batanero to organise its scientific committee. In early 1998 the Scientific Committee was in place and they started to produce a Discussion Document describing the aims of the conference and suggesting the main points to be discussed. Members of the Scientific Committee and the IASE Executive Committee met during the ICOTS-V Conference in Singapore, August 1998 to revise the document.

The Discussion Document, which is reprinted in Part I of this book, was published in the *Newsletter of the International Study Group for Research in Statistics Education* and located at the Conference web site in October, 1998. Shorter versions were also published in the *ISI Newsletter*, *Teaching Statistics* and *IASE Review*. From October 1998 to November 1999, a Call for papers for the conference was announced through the IASE and ISI publications, and through a number of statistics and mathematics education journals; its theme attracted wide interest on the part of statisticians and statistics educators. Proposals for paper presentations were solicited for November 1999 by the Scientific Committee.

The IASE organised a refereeing process with the participation of specialists from different countries to assure fairness and quality in the process of reviewing and selecting the papers to be presented at the conference among the many proposals received. The authors of each accepted proposal were required to complete a preliminary paper by May 1, 2000. These preliminary papers were then put on the web, so that those attending the Round Table Conference could download and read the papers of the various presenters before the actual meeting. The Scientific Committee classified the papers accepted in a number of categories to produce the conference programme and invited some additional participants (both statisticians and statistics educators) to act as reactors for every set of related papers.

The conference was sponsored by the IASE and the ISI, the Institute of Statistical Mathematics in Tokyo and the Japan Statistical Society. The 48 participants who met during five days, included professional and official statisticians, lecturers, researchers and statistics educators with experience in teaching, research or consultancy in different

areas of application (see the list of participants in part I). The participants represented different countries of the five continents, as well as developed and developing countries.

At the conference, the papers were presented and debated and, after the conference, a summary of the discussions was sent to the authors who were given some additional time and were asked to produce a revision of the papers, taking into account the suggestions and discussions held.

As a result of this process we are happy to present today this set of contributions. “Training Researchers in the Use of Statistics” is not a simple topic. In this book the reader will find various analysis of the problems related to this training, and a number of views of ways in which some of these problems might be solved: The controversies on the use of statistics in research; the researchers' attitudes towards statistics; the challenges set by technology; the particular needs of training in specific research fields; the problems of communication among statisticians and researchers are just a few examples of didactical problems that are discussed.

The book is organised in six parts. After the introductory section, which contains the materials related to the conference, several chapters offer a broad view of the didactical problems related to the training of researchers: Part 2 describes the problems related to the training of researchers in particular statistical topics. In Part 3 the challenges set by technology and how this affects the training of researchers is discussed. Part 4 deals with the particular training needs of researchers in areas such as education, social sciences, medicine or biology. International successful experiences to solve challenging problems in the training of researchers are described in Part 5 and Part 6 discusses the didactical problems that underlay statistical consultation. A final chapter presents a synthesis of the main conclusions in the Conference.

The themes and ideas that emerge from these papers should be considered as suggestions for further research more than as definitive answers. There are so many unanswered questions about what the best ways of training future and current researchers are, about how can we change their views and attitudes towards statistics and about how best we can collaborate with them best.

We hope this book will serve as a starting point for other lecturers, researchers and statistics educators to reflect on the statistical training of researchers in empirical sciences, to change their teaching approaches, to improve the interest to collaborate in applied research and to start new didactical research on some of the problems described.

## ACKNOWLEDGEMENTS

We would like to express our recognition to the different people and institutions that made the conference and the publication of this book possible.

A very important role was played by the members of the Scientific Committee, professors Theodore Chadjipadelis (Greece), Joan B. Garfield (USA), Yuki Miura (Japan), David Ospina (Colombia) and Brian Phillips (Australia) who helped the Chair Carmen Batanero (Spain), and supported her decisions throughout the whole planning period, and during the conference. Other members of the IASE Executive Committee M. Gabriella Ottaviani, Dani Ben-Zvi, Gilberte Schuyten, and Lionel Pereira-Mendoza also contributed with their advice and experience to important decisions about the conference.

Both committees are very grateful to the referees who were willing to contribute to this collective study with their expertise in different fields and topics and who provided many valuable comments to help the authors in developing their papers.

The IASE is also grateful to the ISI for supporting this conference and also to the Institute of Mathematical Statistics, and its director Dr. Shimizu by offering to hold this event and for their generous support. It was a great honour for participants to be hosted by this Institute, which is a leader in the statistical practice and research in Japan and at an international level. The IASE also thanks the Japan Statistical Society, in particular the Education Section, and Professors Yuki Miura, Masakatsu Murakami, Toshiro Shimada, and Kensey Araya and the members of the Institute who attended the meeting and the Institute staff for their work in arranging all the details of the local organisation, which served to make the conference more enjoyable and productive.

We are especially grateful to all the authors, discussants and observers, who shared their experiences, research, international projects surveys and reflections on the teaching of statistics and on consultancy in different fields of research and in different statistical topics.

I also wish to thank René Keijser of the International Statistical Institute for designing the cover. And finally and not least important we are indebted to Angela Barrie for her work and patience in helping to revise this manuscript.

*Carmen Batanero*

PART 1

THE IASE ROUND TABLE  
CONFERENCE



## THE IASE ROUND TABLE CONFERENCE

Since 1968, a number of Round Table Conferences have been organised on statistics education topics, initially by the Education Committee of the International Statistical Institute and, since 1996, by IASE (the International Association for Statistical Education). Since 1988 these conferences have been held as satellite meetings to each ICME (International Congress on Mathematics Education).

The goal of the Round Table Conferences is to bring together a small number of experts, representing as many different countries as possible, to share their scholarly work on a given topic area. The round table meetings provide opportunities for developing better mutual understanding of common problems, and for making recommendations concerning the topic area under discussion. A main outcome is a monograph containing a set of refereed papers, which have been prepared for, and discussed during, the conference.

In this book, we present the monograph resulting from the IASE Round Table Conference on Training Researchers in the Use of Statistics, which was held in Tokyo in August 2000. This collection of papers includes an overview of the conference subject, and recommendations for future work in this area.

In this chapter we include the original conference Discussion Document, a list of committee' members and participants and a brief description of the Institute of Statistical Mathematics, where the roundtable was held. The papers in the following chapters were initially prepared in response to the Discussion Document, and were revised both before the conference as a consequence of the referees' comments and after the roundtable to take into account the discussions and suggestions at that meeting.

## DISCUSSION DOCUMENT

*The following people contributed to this document: Carmen Batanero, Theodore Chadjipadelis, Joan B. Garfield, Yuki Miura, David Ospina, M. Gabriella Ottaviani, and Brian Phillips.*

Researchers in different sciences need to collect and analyse data about the phenomena which they study. Conducting empirical research is an exercise that requires conceptual, practical, and also applied statistical skills. The arrival of computers has led to diffusion and intensive use of new statistical techniques, and their application to the analysis of progressively more diverse data sets in a growing number of disciplines. As a result, statistics has become a fundamental tool for experimental researchers, many of whom lack the necessary training in statistics.

Researchers frequently bring statisticians into their research teams. This has two advantages. It helps to ensure that complex data are correctly analysed. It also enables the researcher to learn of new developments in statistical procedures and software tools. However, experimental data analysis and solving practical problems cannot be considered to be solely the responsibility of statisticians. Some fundamental research design issues, and decisions within the data analysis process, as well as the final interpretation of results, require a knowledge of the specific discipline area that is

generally deeper than that which a statistician is able to contribute.

Inappropriate attitudes or lack of knowledge on the part of researchers about the central role that statistics can play in research may affect the communication and collaboration between statisticians and researchers in other fields. Psychological heuristics and biases also affect the processes of decision taking and interpreting of random experiment results. Researchers, for example, sometimes overestimate the power of their research methods, or attribute too much confidence to the reliability (replicability) of their findings.

As a consequence, statistics courses can be seen to be a crucial part of the general training received by new researchers. Within many masters and doctoral programmes in other disciplines, courses on data analysis concepts and procedures and, more generally, on statistical reasoning and research methodology are included. Therefore, the study of difficulties and obstacles that new researchers face when learning the contents of these courses should be of fundamental concern to statistical educators. Key issues are the existing concepts and attitudes that the researchers bring to these courses, as well as the methods by which they are expected to develop their statistical understanding.

That there are inadequacies in such training programmes may be inferred from the degree of controversy that exists within some research communities about the use of statistical tests and other statistical procedures. This controversy has increased in recent years within some professional research organisations. Important shifts have been proposed, and in some cases implemented, in editorial policies regarding the publication of statistical analysis results.

However, there is still a great deal of evidence that researchers do not have the necessary understanding of statistical concepts and processes to appreciate what methods are really appropriate to their needs. It is therefore crucial that statistical educators consider empirical findings about researchers' uses and misuses of statistics from a didactic perspective, so that they can contribute significantly to the development of appropriate training programmes for researchers.

IASE, the International Association for Statistical Education, is convening a Research Round Table on this topic. It is hoped that statistical educators across the world will wish to contribute to the international discussion and thereby extend understanding about the problems of training researchers in the use of statistics.

### SOME RESEARCH QUESTIONS

The overall intention is to study the problem of training researchers in the use of statistics, in all its many dimensions. One aspect of this relates to the considerable variation that pertains in the statistical methods that the trainee researchers require, dependent upon which scientific context they will be working in. A wide-ranging discussion is needed within the statistical education community itself in order to identify prevailing views on how researchers may be optimally trained.

There is, however, also a need to develop mutual understanding of the problems by encouraging dialogue between statistical educators and representatives of other scientific disciplines. The following broad areas are expected to form the main structure of the Round Table programme and its deliberations.

1. *What are the specific statistical competencies that researchers in different disciplines should acquire in their postgraduate training?*

Statistics is an important component in the training of new researchers within

masters and doctorate courses. There are a number of reasons for including a statistical component in such training. Scientists need: a basic knowledge of statistics to carry out simple statistical tasks themselves, a level of understanding that allows them to identify statistical errors in research literature, and the ability to recognise situations where they should seek a statistician's help.

2. *What are the particular needs and problems in the statistical training of researchers in specific fields? Of what good examples of successful teaching experiments in specific fields do we know?*

Many domains of scientific knowledge have become highly specialised. Scientists in different disciplines, have different needs and opportunities to apply statistics. Their views about statistics may differ, according to their previous statistical and mathematical training and research backgrounds. This may be reflected in their having different training needs. Analysis of these issues, and examples of course design and evaluation could provide examples for future developments.

3. *What are the main learning problems, misconceptions and errors concerning particular advanced statistical concepts?*

Research into the learning of advanced statistics is starting to emerge. Students' difficulties on topics such as hypothesis testing, estimation, correlation, the normal distribution, are now starting to receive attention from researchers in statistical education. However, much more research on these problems, and on students' difficulties in other advanced statistics topics, is needed. It is also important to communicate the outcomes of such research to statistical educators, so that they can be taken into account in the design of research training courses.

4. *How should we design/evaluate courses for training researchers in particular statistical topics? What good examples do we have of successful teaching experiments in advanced statistics?*

Because of the speed at which statistical techniques develop and diversify, researchers frequently need to update their understanding of specific procedures or learn about new techniques that they should be employing in their research projects. One main problem is the design and evaluation of courses on topics such as multivariate analysis, Bayesian inference, sampling design, categorical data analysis, experimental design, quality control, etc., directed at new and senior researchers.

5. *What are the effects of technology on the statistical training of researchers?*

Research on the Role of Technology in Teaching and Learning Statistics was the theme of the previous Round Table Conference held in Granada in 1996. The conference demonstrated that educational technology does afford us with a large variety of strategies for teaching statistics. However, a number of problems were also identified, e.g. inadequate preparation of teachers, inappropriate curriculum content and structure, or lack of appropriate assessment methods. The extent to which these possibilities and problems could affect the training of researchers in the use of statistical software, as well as the training needs of researchers, will be addressed.

6. *What errors are frequent in the use of statistics by researchers?*

Because the logic of statistical inference is difficult to grasp, its use and interpretation is not always adequate. It is important for the scientific community to be made aware of common errors and misinterpretations in the use of statistics.

7. *How the researchers attitudes towards statistics affect the current role of data analysis in experimental research?*

The role of statistics in research is sometimes conditioned by researchers' views of statistics and the utility of statistics, including overestimating the power of data analysis, considering statistics as a mechanistic process, or complete rejection of the quantitative approach to research. The task of assessing the role of statistical methods in empirical research is also complicated by the facts that; (a) researchers use different research methods to achieve the same goals, (b) the theoretical, practical and statistical constraints on researchers differ when the researchers have different objectives, and (c) the relationship between the substantive and statistical hypotheses is often oversimplified by researchers.

8. *Could we compare consultation to a teaching/ learning process? Are there problems of communication in the collaborations between statisticians and experts in different disciplines?*

Statisticians who frequently collaborate with researchers need to understand enough about their colleagues' discipline areas as well. They must also learn to communicate statistical issues and results effectively to researchers. Problems can arise because of differences between statistical, technical scientific and everyday use of language. Statistical educators can, and should, be involved in improving the learning processes underlying the skills associated with providing statistical consultation.

9. *What statistical concepts and procedures are informally learned from reading research literature?*

Statistical language and statistical reasoning allow a specific way of communicating information and reaching conclusions. The way in which this resource is used in research literature to support researchers' results, and the learning processes involved in reading published research studies, need to be examined from the perspective of statistical education. A related topic is the need to develop criteria that can be used by researchers to evaluate the statistical methods found in research reports.

## THE INSTITUTE OF STATISTICAL MATHEMATICS

Since its found as the only national institute of statistics in Japan, the Institute of Statistical Mathematics has exerted a powerful influence on the study and research of statistical science. The ever-increasing needs for statistical methods and ideas in various fields of science and technology led the Institute to reorganise itself in 1985 as an inter-university research institute which puts a major emphasis on research collaboration with all disciplines of science. In 1997, in order to foster collaborative research projects even more effectively and to intensify the impact of statistical science in academia, industry, and government, the Institute restructured its two attached centres and established positions for foreign researchers as visiting professors.

At present, the Institute consists of four departments, two centres, two councils, and a committee. The four departments: Fundamental Statistical Theory, Statistical Methodology, Prediction and Control, and Interdisciplinary Statistics form the active core of the Institute with its 55 academic staff, carrying out research either on statistical theory or on its application to other fields of science and industry.

The Department of Fundamental Statistical Theory and its four divisions address the

fundamental aspects of theoretical statistics. In the six divisions of the Department of Statistical Methodology, efforts are concentrated on improving statistical methods and creating new techniques for analysis. The seven divisions in the Department of Prediction and Control are specifically concerned with development of innovative approaches to understand and possibly control phenomena of a stochastic nature. The Department of Interdisciplinary Statistics, with its three divisions, is set up in order to transfer methodological developments to other disciplines and to receive, in turn, impetus that urges the creation of new statistical methods.

The two centres attached to the Institute have the aim of supplementing its activities. As of April 1997, their names and structures have changed in order to stimulate cross-disciplinary statistical research and to provide researchers both inside and outside the Institute with adequate computational and informational resources. The Centre for Development of Statistical Computing consists of two divisions. Together they undertake research on statistical computing, and also facilitate the use of computers and network connections. The Centre for Information on Statistical Sciences encourages research collaboration, publicises research findings through journals and the internet, and seeks to cultivate statistical thinking in the general public. The Centre has an additional division for foreign visiting professors.

In addition to the departments and centres, the Institute has a section of 12 technical staff that work on special jobs including maintenance of computer systems and bibliographical service. The Institute has an excellent library of books and journals, not only in pure statistics, but also in fields of specific interest to researchers (e.g., physics, genetics, and social sciences). Lastly there is also a division of 18 officials who take care of general affairs. The Institute devotes itself to educating young statisticians as well. As a constituent of the Graduate University for Advanced Studies (Department of Statistical Science, School of Mathematical and Physical Science), the Institute offers graduate programs leading to a Ph.D. degree.

## COMMITTEES

The International Association for Statistical Education is grateful to the following people, who contributed to the organisation of the conference, the selection and revision of papers.

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In addition to the speakers, and the members of the committees, the following people participated in the revision and selection of papers:

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