

Teaching Statistics in School Mathematics-Challenges for Teaching and Teacher Education

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Teaching Statistics in School Mathematics-Challenges for Teaching and Teacher Education

A Joint ICMI/IASE Study:
The 18th ICMI Study



International Commission on
Mathematical Instruction



Springer

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Preface

1 Introduction

The teaching of statistics in secondary school has a long tradition in countries like France, Spain and the United Kingdom. However, because statistics is becoming increasingly important in modern society, the relevance of developing statistical thinking in students across all levels of education has grown. Consequently, the new curricula published in the past years in many countries like Brazil, Costa Rica, South Africa, Spain, the United Arab Emirates and the United States of America include statistics from the first year of primary school level (6 year-old children).

Changes in what is expected in the teaching of statistics do not just concern the amount but also the quality of the content. Until recently, statistics in many school curricula was reduced to tasks in which learners were given small organised data sets and were asked to produce specific graphs, compute simple statistics (e.g., the mean or median) or answer simple direct questions. This formula-based approach to statistics resulted in students who were ill-prepared for tertiary level statistics and adults who were statistically illiterate.

The current recommendations, even for primary school levels, suggest a data-orientated approach to the teaching of statistics where students are expected to: design investigations; formulate research questions; collect data using observations, surveys, and experiments; describe and compare data sets; and propose and justify conclusions and predictions based on data. Learners are expected to deal with data in significant contexts and to take a critical stance on the analysis and interpretation of data and especially the abuse of data and statistics. The importance of developing statistical thinking and reasoning and not just statistical knowledge in students is being emphasised in many curricula.

Concurrent with these changes, the International Statistical Institute (ISI) started to pay more attention to teaching statistics in schools in the mid seventies, when the socio-economic conditions in developed countries, frequent use of quantitative information in newspapers and more widespread use of personal computers led to increasing demands on statistics education for the general citizen. The International Conferences on Teaching Statistics (ICOTS) were started in 1982 by the ISI and

later continued by the International Association for Statistical Education (IASE) to bring together statistics teachers at all levels, and from all disciplines and countries, every four years.

Changing the teaching of statistics in schools will depend on the extent to which teachers can be convinced that statistics is one of the most useful themes for their students and the extent to which these teachers are adequately prepared to teach statistics at school level. Although interest in the education and professional development of mathematics teachers has increased in the past 20 years and there is now a body of research results on this issue, current literature seems to indicate that we are not in the same place in the specific case of statistics. This is shown by an analysis of research literature, for example papers published in the *Journal of Mathematics Teacher Education*, as well as in survey papers and handbooks quoted throughout this book that pay little attention to the teaching of statistics.

This book is a consequence of and presents the results from the Joint ICMI/IASE Study, *Teaching Statistics in School Mathematics-Challenges for Teaching and Teacher Education*, organised by the International Commission on Mathematical Instruction (ICMI; www.mathunion.org/ICMI/) in collaboration with the International Association for Statistical Education (IASE; www.stat.auckland.ac.nz/~iase/) and intended to address the lack of attention to teaching statistics by promoting research specifically focussed on the education and professional development of teachers to teach statistics.

2 Study Background

Since the mid-1980s, ICMI has found it important to involve itself directly in the identification and investigation of issues or topics of particular significance to the theory or practice of contemporary mathematics education and to invest effort in mounting specific ICMI studies on these themes.

At the same time, in the past three decades a statistics education research community has developed, linking people from various backgrounds (statisticians involved in teaching statistics in service courses at the university; statisticians working in statistical offices; mathematics educators; researchers in statistics education; educators; and psychologists), leading to the creation of the International Association for Statistical Education (IASE), in 1991. Conversations between ICMI and the IASE made clear there was a common interest in organising a Joint Study related to current problems in the teaching of statistics within school mathematics. This interest arose from the fact that, in spite of recommendations to increase the presence of statistics teaching at the school level, students in these levels do not acquire a statistical literacy adequate to function in an information-based society and to progress in the study of statistics at higher levels such as university or professional training.

The invitation from ICMI to collaborate on a Joint Study was accepted by the IASE. Subsequently, IASE suggested that this Joint Study merge with the 2008 IASE Round Table Conference, intended as part of a series of conferences started by the ISI and held by the IASE every four years. As a consequence of this agreement, the Joint ICMI/IASE Study Conference was held at the Instituto Tecnológico y de Estudios Superiores, Monterrey (ITESM), Monterrey Campus, Mexico in July 2008. This book is the final outcome from this Conference.

3 Joint ICMI/IASE Study Conference

Many people have been involved, first in the Joint ICMI/IASE Study conference and then in the production of this book. The work started with the appointment of an International Programme Committee in 2005 whose members worked collaboratively to prepare the Discussion Document. This document described the aims, topics and related research questions for the Joint Study, included a Call for Papers and was released in October 2006. The document was published in main mathematics and statistics education journals and also disseminated through statistics and mathematics education conferences and associations.

A specification of the Joint Study was its inter-disciplinary character, and therefore, the Programme Committee invited participation from mathematicians, mathematics educators, statisticians, (including official statisticians working at statistical agencies), and statistics educators, as well as psychologists and university lecturers of other disciplines where statistics is used as a tool. The Committee was specifically interested in inviting people with different levels of experience, including people who were well known in the area, new researchers who were just forming their views and teacher educators who were training the future mathematics teachers who would be delivering statistics at school levels.

Preliminary papers were received by October 2007 and reviewed by external referees over the next few months. Statistics and mathematics educators from all across the world contributed to the selection and improvement of the papers in the refereeing process. The papers selected by the International Programme Committee after the refereeing process were rewritten and received between March and April, 2008. The papers accepted covered a variety of topics and came from around the world, including both developed and developing countries.

The conference theme: *Teaching Statistics in School Mathematics: Challenges for Teaching and Teacher Education* had appeal for both mathematicians and statisticians, proving that the time was ripe for collaboration between the ICMI and the IASE. All together 109 participants representing 33 countries from all parts of the world participated in the conference. The Joint Study Conference was structured around six different topics, each organised by two members of the International Programme Committee. The six topics, briefly described below, served as an initial focus for potential papers and to organise the working groups in the conference.

1. *The current situation of teaching statistics in schools*, organised by Dani Ben-Zvi and Chris Reading. The interest in this group was a reflection of the status of statistics in the curricula of different countries; comparing the statistical content included in national curricula and tests and how the teaching of statistics at the school level specifically compared to teaching other topics in the school mathematics curriculum. The working group was also interested in analysing the differences between statistical literacy and reasoning and the teaching of statistics through project work.
2. *Teachers' attitudes, knowledge, conceptions and beliefs in relation to statistics education*, organised by Carmen Batanero and Gail Burrill. This group discussed teachers' beliefs and attitudes towards statistics and the effect of these beliefs and attitudes on the way statistics is taught. A second interest was in the analysis of the mathematical and pedagogical knowledge teachers need to teach statistics and on research instruments and strategies useful for determining the knowledge of statistics and of teaching statistics that teachers possess.
3. *Analysing current practices in teacher education regarding the teaching of statistics*, organised by Doreen Connor and Lionel Pereira-Mendoza. The aim of this group was to compare current training of teachers to teach statistics in different countries and to analyse the role of technology, current materials and teaching practice in developing teachers' competence to teach statistics.
4. *Empowering teachers to teach statistics: A look into the future*, organised by Joachim Engel and Maxine Pfannkuch. While Topic 3 analysed current practices in training teachers, in Topic 4 the focus was on innovative proposals or materials to change the current practice and improve the preparation of teachers.
5. *Training teachers in developing countries*, organised by Jun Li and Victor Polaki. A common concern of both the ICMI and the IASE has been related to the provision of research and teaching opportunities in statistics in developing or transitional countries. In the Joint Study Conference a working group was organised to reflect on the specific problems these countries have in training their teachers and in developing statistics education in their schools.
6. *Building collaboration between mathematics and statistics educators in teacher education*, organised by Joan Garfield and Maria Gabriella Ottaviani. Given the current interest from national statistical offices and statistics associations in developing statistical literacy for all citizens, this working group analysed examples from these institutions of collaborations in developing teaching materials or offering support to statistics teachers. Other examples of collaboration included collaborative projects between different university departments, university and schools or even between different countries.

The conference papers were distributed to participants before the conference and were published in the conference proceedings, edited by Carmen Batanero, Gail Burrill, Chris Reading and Allan Rossman, and published by ICMI and IASE. These proceedings are available from the IASE publication webpage at www.stat.auckland.ac.nz/~iase/publications. Each paper was assigned a reactor who read the paper before the conference and discussed the paper in special discussion

sessions organised within the conference. Results from these discussions and conclusions from the working groups were presented in a final plenary session and also served as a basis to structure this book.

Other plenary sessions included an Opening lecture on the theme *Preparing teachers to meet the challenges of statistics education*, by Joao Pedro da Ponte, Portugal, and three panel sessions. The first, *Fundamental ideas in statistics and how they affect the training of teachers* was coordinated by Gail Burrill, United States of America. Since different curricula around the world include different statistical content at school level, the presenters offered their reflections and analyses about what basic statistical ideas and types of reasoning would be needed to educate statistically literate citizens. Speakers were Martha Aliaga, United States of America; Rolf Biehler, Germany; and Ernesto Sánchez, Mexico.

The second panel session, *The interplay of probability and statistics in teaching and in training the teachers* was organised by Maria Gabriella Ottaviani, Italy. Although the main focus of the conference was statistics, this panel reflected on possible relationships between statistics and probability in the curriculum and how the different views of probability (classical, frequentist, subjective) affect the teaching of statistics. Speakers were Manfred Borovcnik, Austria; Jean Claude Girard, France; and Delia North, South Africa.

Technology today is changing not only the way we work in mathematics and statistics but also the way we teach these topics. Dave Pratt, United Kingdom organised a discussion around *Technology in the teaching of statistics: Potentials and challenges in preparing the teachers*. Speakers were Dani Ben-Zvi, Israel; Doreen Connor, United Kingdom; and Anthony Harradine, Australia.

The conference was held at the Monterrey Campus of the Instituto Tecnológico y de Estudios Superiores de Monterrey (ITESM), (www.mty.itesm.mx/), a well-established Mexican educational institution that was founded in 1943 with campuses distributed throughout the country and other Latin American countries. This institution and in particular the Mathematics and Statistics Department supported the conference, offering its facilities and organising different social activities that provided opportunities for participants to interact informally. Other institutions supporting the conference were the American Statistical Association, the Mexican Statistical Association and the Centro de Investigaciones y Estudios Avanzados (CINVESTAV). The Programme Committee is indebted to these institutions as well as to the local organising committee: Blanca Ruiz (Chair), Armando Albert and Tomás Sánchez, all lecturers of ITESM, and Ernesto Sánchez, CINVESTAV, México.

The Joint Study Conference was held the week before ICME-11 (the International Congress on Mathematical Education). The following weekend an *Encuentro Latinoamericano de Educación Estadística* (ELEE, Latin American Statistics Education Meeting) was organised. The aim of this meeting was to gather together Latin-American statistics educators and teachers taking part in either the Joint ICMI/IASE Study Conference or ICME 11 with the purpose of exchanging experiences, expanding their statistics education knowledge, widening their network of contacts and establishing projects for future collaboration. The ELEE

meeting was attended by about 80 participants and included panel discussions, presentations, workshops, posters and attendance at the closing sessions of the Joint ICMI/IASE conference.

4 Structure of This Book

To produce a monograph that covers the state of art for the Joint ICMI/IASE Study, the editors fixed a tentative content and a tentative structure for the book in the Call for Papers. This structure took into account the papers presented and the discussions held at the conference and tried to assure coherence and completeness in the monograph. The Call for Papers was distributed to participants in the conference, who were encouraged to form teams to prepare a common chapter in the book when the papers presented in the conference dealt with complementary themes.

The book is organised into four main parts, each consisting of several chapters. Part I: *Global Perspective* derives from the conference work in Topics 1 and 5 and some papers presented in Topic 3. This part offers examples of how statistics is conceived in the mathematics school curriculum around the world, including developed and transitional countries, and how mathematics teachers who are responsible for the teaching of statistics are currently trained. It consists of short chapters organised around two themes. The first one, the statistics school curricula around the world, deals with curricular issues in Brazil, United States of America, Uganda and South Africa. The second theme (or section) discusses the particular experiences of training teachers in Germany Honduras-Costa Rica, Iran, the United States of America, and the Philippines.

Parts II, III and IV consist of chapters each of which considers a different theme. The chapters take into account previous research presented in the conference and discuss the topic in a general way. Specific research or experiences are included in some cases, but particular examples are not the central focus of these chapters. Instead they complement the theme of the part and serve to enlighten general discussion on that theme. Chapters in Part II, *Fundamentals for Teaching Statistics*, include discussion of the following topics of importance in the teaching of statistics, three of which (the fundamental statistical ideas, the role of probability in the statistics curriculum, and the challenges set by technology) were debated at the conference plenary panels. Other topics that arose in the working group discussions as relevant for the teaching of statistics (modelling in probability and statistics, differences/complementarities between statistics and mathematics, the role of assessment in teaching and learning, and teaching statistics through investigative projects) are also discussed in this part.

Research on teachers' knowledge and professional development in statistics, that is, chapters in Part III, *Teachers' Beliefs, Attitudes and Knowledge*, result from the conference work in Topic 2. This part also includes a collective effort to present a state-of-the-art summary of the research on this topic and implications for training

teachers to teach statistics, as well as suggestions about how to advance research in this area. After reflection on the components of teachers' attitudes, beliefs and classroom practices and how they are interrelated and affect teaching and learning of statistics, the part contains a series of chapters each focussing on teachers' knowledge or learning about a different statistical topic. Three chapters are focussed on models for teachers' statistical knowledge and how to measure this type of knowledge.

Chapters in Part IV, *Challenges and Experiences in Teacher Training*, derive from the conference working groups 3 and 4 and analyse questions and activities of relevance in training the teachers. This part starts with an expansion of the opening lecture (Preparing teachers to meet the challenges of statistics education) and then discusses challenges and possibilities that real data, case analysis, statistical investigations, technology and distance training offer to educate the teachers. Ways to develop students' and teachers' statistical thinking and literacy are also discussed. This part finishes with an overview of relevant examples of collaboration from statistical offices and associations to improve the preparation of mathematics teachers to teach statistics in different countries. In addition, the book includes an overview and introduction to the different parts, written by the editors.

5 Final Notes

The book is directed to both mathematics and statistics educators, including in-service teachers, students preparing to be teachers, teacher educators, people involved in curricular development in statistics as well as researchers in statistics and mathematics education and can be of interest to any in that audience. A primary goal of the book is to help teacher educators and educational authorities to clearly perceive the current need for all the students to be statistically literate and able to reason statistically, the differences and complementarities between statistical and mathematical thinking and literacy, and consequently the relevance of adequately preparing mathematics teachers to teach statistics.

Parts III and IV contain very useful information about the knowledge required by teachers, their current difficulties related to teaching statistics and possible strategies for educating the teachers. These parts can be of interest to teachers themselves, as an important part of research summarised in these chapters both in learning difficulties or teaching strategies is applicable to students. In the same way, the basic ideas for teaching statistics described in Part II are common in both the training of students and teachers.

This book is designed to be useful to researchers in mathematics education and statistics education with the hope that it will foster further research in the problems related to educating teachers to teach statistics at different school levels, from primary to secondary school. Finally, we hope this book will prove helpful towards improving the teaching of statistics at school level and increasing the statistical literacy and the statistical thinking of both teachers and students.

While it was a large task, the editors found that the experience of editing this book and working with such a varied group of international authors has been a privilege for us. We recognise that we could not have completed this book without the collaboration and cooperation of many people. Consequently, we are most grateful for the dedication, expertise, and professionalism of authors and referees, for the advice and feedback from ICMI and IASE officers, and particularly we are most grateful for the work of the International Programme Committee, both in the planning of the Joint ICMI/IASE Study Conference and in the initial stages of the production of the book.

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