Discussion document for the eighteenth ICMI study : on statistics education in school mathematics

L'Enseignement Mathématique (2) 53 (2007), 179–191

COMMISSION INTERNATIONALE DE L'ENSEIGNEMENT MATHÉMATIQUE

(THE INTERNATIONAL COMMISSION ON MATHEMATICAL INSTRUCTION)

DISCUSSION DOCUMENT FOR THE EIGHTEENTH ICMI STUDY

STATISTICS EDUCATION IN SCHOOL MATHEMATICS: CHALLENGES FOR TEACHING AND TEACHER EDUCATION (JOINT ICMI/IASE STUDY)

1. Background

Since the mid-1980s, the International Commission on Mathematical Instruction (ICMI, http://www.mathunion.org/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 an 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, mathematics educators, and psychologists), leading to the creation of the International Association for Statistical Education (IASE, http://www.stat.auckland.ac.nz/~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 next IASE Round Table Conference (June 30–July 4, 2008, Instituto Tecnológico y de Estudios Superiores, Monterrey, Mexico), just before the Eleventh International Congress on Mathematics Education (ICME-11; Monterrey, Mexico, July 6–13, 2008). In this document, we describe the Joint Study focus, suggest some preliminary research questions, call for participation in the Study and give some general guidelines and deadlines.

2. JUSTIFICATION

THE SITUATION OF TEACHING STATISTICS AT THE SCHOOL LEVEL

Today statistics is part of the mathematics curricula for primary and secondary school classes in many countries. The reasons for including statistics teaching have been repeatedly highlighted over the past 20 years (e.g., by Holmes, 1980; Hawkins, Jolliffe & Glickman, 1991; Wild & Pfannkuch, 1999; Gal, 2002; Franklin et al., 2005): usefulness of statistics and probability for daily life, its instrumental role in other disciplines, the need for a basic stochastic knowledge in many professions, and the important role of statistics in developing critical reasoning.

The tendency towards a data-orientated teaching of statistics is shown in the curricular orientation for primary school levels where students are expected to design investigations, formulate research questions, collect data using observations, surveys, and experiments, describe and compare data sets, use and understand statistical graphs and measures, propose and justify conclusions and predictions that are based on data (e.g., NCTM, 2000; SEP, 2006; Lajoie, 1998; Burrill, 2006; Burrill & Camden, 2006). These documents focus on developing statistical reasoning, which is different from mathematical reasoning, both being essential to modern society and complementing each other in ways that strengthen the overall mathematics curriculum for students (Gattuso, 2006; Scheaffer, 2006).

However, these curricular recommendations are hardly ever followed, as the teaching of statistics is frequently reduced or forgotten and, at best, taught in a formal way with few examples of real applications (Meletiou, 2003). The teaching of statistics often consists only of doing computations or proving mathematical theorems with scarce opportunity to design experiments, analyse data or connect statistics with the general process of inquiry. As a consequence, students finish secondary school with little understanding of basic principles underlying data analysis, which explains many of the problems they encounter in the use of statistics in their everyday and professional lives or in statistics courses at the university level.

CHALLENGES IN THE INITIAL TRAINING AND ONGOING PROFESSIONAL DEVELOPMENT OF TEACHERS

Changing the teaching of statistics in schools will depend on the extent to which we can convince teachers that statistics is one of the most useful themes for their students (Gattuso, 2006). A better preparation of these teachers, who frequently lack specific preparation in statistics education, is also required (Russell, 1990; Gattuso & Pannone, 2002; Mendonça, Coutinho, & Almouloud, 2006). Even when many prospective secondary teachers have a major in mathematics, they usually study only theoretical (mathematical) statistics in their training. Few mathematicians receive specific training

in applied statistics, designing sample collections or experiments, analysing data from real applications or using statistical software. These teachers also need some training in the pedagogical knowledge related to statistics education, where general principles that are valid for geometry, algebra or other areas of mathematics cannot[1]) always be applied (Russell, 1990; Batanero, Godino & Roa, 2004). The situation is even more challenging for primary teachers, few of whom have had suitable training in either theoretical or applied statistics, and traditional introductory statistics courses will not provide them with the didactical knowledge they need (Franklin & Mewborn, 2006).

Research in statistics education shows that textbooks and curriculum documents prepared for primary and secondary teachers might not offer enough support. Sometimes they present too narrow a view of concepts (for example, only the classical approach to probability or inference is shown); applications are at other times restricted to games of chance or are not based on analysis of real data; finally in some of them the definitions of concepts are incorrect or incomplete (Moncecchi & D'Argenzio, 1994; Cardeñoso, Azcárate & Serradó, 2005).

Attention should also be paid to teachers' statistical conceptions and beliefs. Research in statistics education is showing that many teachers unconsciously harbour a variety of probabilistic and statistical difficulties and errors (misconceptions) that might be shared with students (Rubin & Rosebery, 1990; Makar & Confrey, 2004; Stohl, 2005). There is little opportunity for teachers' professional development in statistics, due to the lack of practice in either teaching this topic or applying statistics to analyse educational data. As a consequence, teachers might realise their need for further professional development in statistics (Watson, 2001; Gattuso & Pannone, 2002; Mendonça, Coutinho & Almouloud, 2006) or even feel uncomfortable in teaching this topic and consequently have a tendency to reduce or omit it. The pedagogical content knowledge required for teaching and the way teachers use their statistical knowledge when teaching statistics should also be taken into account (Mickelson & Heaton, 2004).

The significant research efforts focusing on mathematics teacher education and professional development in the past decade have not been reflected in statistics education. This is evident in conferences (e.g., the ICMI Study 15), journals (e.g., *Journal of Mathematics Teacher Education*), surveys, and books that hardly take into account the particular case of statistics. This omission needs to be addressed by promoting research specifically focused on the education and professional development of teachers to teach statistics (Shaughnessy, in press).

Specificity of statistics education

The above problems do not concern only mathematicians or mathematics educators. On the one hand, statistical offices in charge of producing statistics for a variety of applications in social, industrial, political, scientific or everyday life are increasingly concerned about the *statistical illiteracy of citizens*. These citizens are often unable

[1]) For example, in arithmetic or geometry an elementary operation can be reversed and this reversibility can be represented with concrete materials. This is very important for young children, who still are very linked to concrete situations in their mathematical thinking. When joining a group of two apples with another group of three apples, a child always obtains the same result (5 apples); if separating the second set from the total he/she always returns to the original set, no matter how many times this operation is repeated. These experiences are very important to help children progressively abstract the mathematical structure behind them. In the case of random experiments we obtain different results each time the experiment is carried out and the experiment cannot be reversed.

to correctly interpret simple statistical information presented in the press, Internet and other media, and they are not always willing to cooperate in providing sound data needed to produce these statistics, for example the census. As a consequence there is an increasing involvement of statistical offices and associations in producing materials and organising actions that help increase statistical literacy (e.g. Barbieri & Giacché, 2006; Ottaviani & Rigatti, 2006), that is, the ability to understand and critically evaluate statistical results that permeate our daily lives — coupled with the ability to appreciate the contribution that statistical thinking can make in public and private, professional and personal decisions (Wallman, 1993; Gal, 2002).

On the other hand, the strong specificity of statistics education is reflected in the philosophical, ethical, procedural and even political questions that are still being debated within statistics and its applications, which do not arise in other areas of mathematics. Statistics is much more closely related than mathematics to other sciences (from linguistics or geography to physics, engineering or economics) where it is used as the language and method of scientific enquiry and from which many statistical methods were developed. In this sense it is also easier in statistics than in mathematics to establish connections with other school curricular areas and sometimes it has been argued that statistics should be taught outside the mathematics classroom (Pereira-Mendoza, 1993).

Today statistics is separate from mathematics at the university level in many countries where distinct majors are offered in the training of mathematicians and statisticians. Statistics research encompasses a variety of institutions, conferences and journals. Finally, we cannot ignore the wide contributions to research in statistics education from areas other than mathematics, for example in statistics, psychology and education in other fields (Vere-Jones, 1995; Shaughnessy, 1992; Shaughnessy, Garfield & Greer, 1996; Batanero, 2004; Jones, 2005; Shaughnessy, 2006, in press). Moreover, there has recently been a large increase in statistics education research outside the mathematics education community[2]). Although the topic of training teachers has been considered (e.g., Hawkins, 1990; Watson, 1998; Friel & Bright, 1998), there has not been a sustained effort in exploring, explaining and improving teachers' statistical conceptions, attitudes and beliefs. Given the increasingly prominent role of statistics in both curricula and daily life, it is essential that statisticians, mathematicians, mathematics educators and others collaborate on the design and implementation of teacher education programs for both pre-service and in-service mathematics teachers (Franklin & Mewborn, 2006).

3. Focus

The above rationale led the International Commission on Mathematical Instruction (ICMI) and the International Association for Statistical Education (IASE) to start the process of organising a Joint Study to *analyse the teaching of statistics at school level and make recommendations about how to improve the training of mathematics teachers to better succeed in educating statistically literate students*. This specific Study brings

[2]) This is reflected in the ICOTS and IASE Round Table Conference proceedings (most of which are available from the IASE web page at http://www.stat.auckland.ac.nz/~iase/), books such as Gal & Garfield (1997), Sedlmeier (1999), Ben-Zvi & Garfield (2004), and in the 2002 creation of the *Statistics Education Research Journal*.

the mathematics and statistics education communities together to work in collaboration on a common problem and might serve to continue this collaboration in future work.

The Joint Study reflects on the specificity of statistics teaching at the school level and teachers' learning, and provides an overall picture of the current situation in both the teaching of statistics in schools and the pre-service education of mathematics teachers. We intend to develop research questions and invite new research to produce some recommendations and materials that can be used in the training of both prospective teachers at university level and in-service teachers who have never had an adequate preparation to teach school statistics. Since initial teacher training in the area of statistics is constrained by time, the Joint Study will concentrate on defining the essential elements of statistics, didactic knowledge and experiences for teacher learning. Statistics taught at the university or professional education levels will not be considered in order to restrict the focus of the Study to a more manageable scope.

Statistics and probability are linked in school mathematics in many countries and within mathematics theory and practice. For this reason, some references to probability will be unavoidable in the Study, in particular when dealing with statistical inference. However the Joint Study is not focusing on probability itself. Instead we will build on some previous work, such as the recent international survey book on teaching probability at school levels edited by Jones (2005).

This Joint Study is related to the ICMI Study 15, *The Professional Education and Development of Teachers of Mathematics* in the sense that it focuses on mathematics teachers and therefore, many of the conclusions of the above Study can also be applied to the case of statistics. A primary difference is that we will concentrate on specific content for the curricula for teachers' initial training which is largely absent at the present time. We will focus on this initial training, since, as argued above, there has been little chance for professional development in teaching statistics to date. However, papers describing successful examples of professional development in teaching statistics are also welcome. The Joint Study is also supported by the work at the IASE Round Table conference on curricular development in statistics (Burrill & Camden, 2006) and the International Statistical Institute Round Table conferences on Training Teachers to Teach Statistics (Hawkins, 1990) and on Introducing Data Analysis into Schools (Pereira-Mendoza, 1993).

4. Audience and potential participants

We hope the Joint Study results can be useful for 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.

A specification of the Joint Study is its interdisciplinary character, and therefore, we expect participation from mathematicians, mathematics educators, and statisticians, including official statisticians working at statistical agencies, as well as psychologists and teachers of other disciplines where statistics is used as a tool. We are specifically interested in inviting people with different levels of experience, including people who are well known in the area, some new researchers who are just forming their views, and some teacher trainers who are training the future mathematics teachers who will be delivering statistics at school levels.

5. Topics and preliminary research questions

The Joint Study will be structured around six different topics, each organised by two members of the International Programme Committee. Below we describe some questions around each topic that can serve as an initial focus for potential papers and later be developed, expanded or modified.

Topic 1. *The current situation of teaching statistics in schools.*

Organisers: Dani Ben-Zvi (dbenzvi@univ.haifa.ac.il) and Chris Reading (creading@une.edu.au)

1. What is the current situation of teaching statistics at primary and secondary school levels in different countries? What status does data handling and statistics have in the curricula of different countries? What statistical content is included in national curricula and tests and how does that affect teaching? How can the current emphasis on assessment and accountability limit or reinforce statistics education at primary and secondary school levels?

2. Is statistics taught as a purely mathematical topic or is it integrated into other subjects such as science and social studies? What are the main current problems in the way statistics is taught? How does the teaching of statistics at the school level specifically compare to teaching other topics in the school mathematics curriculum?

3. What is the difference between teaching statistics and teaching statistical literacy? What specific teaching of statistical reasoning is needed?

4. How should statistics be taught through project work, relating statistics to applications and expanding the teaching of statistics outside the mathematics classroom?

5. What are good examples of teaching statistics in the schools?

6. What are the main challenges associated with training students for the transition from school to university?

Topic 2. *Teachers' attitudes, knowledge, conceptions and beliefs in relation to statistics education.*

Organisers: Carmen Batanero (batanero@ugr.es) and Gail Burrill (burrill@msu.edu)

1. What are teachers' attitudes and beliefs about statistics and its role in school mathematics? How do teachers' attitudes and beliefs about statistics and teaching statistics affect their pedagogical approaches?

2. What substantive and deep learning in statistics must teachers undergo[3]) to be able to develop statistical concepts and enquiry in their students? How much formal probability is needed?

3. What research instruments and strategies are useful for determining what knowledge of statistics and of teaching statistics teachers have?

4. What basic pedagogical content knowledge and competencies do teachers require to successfully teach statistics at different school levels? How are all these competencies related?

---

[3]) For example, what knowledge is needed about the cycle of scientific investigation, formulating questions to be answered with data, problems of measurement, data collection and its design, randomization, the role of sample size, bias and variation, drawing conclusions and decision-making under uncertainty, and informal risk assessment?

TOPIC 3. *Analysing current practices in teacher education regarding the teaching of statistics.*

Organisers: Doreen Connor (doreen.connor@ntu.ac.uk) and Lionel Pereira-Mendoza (lionel@iammendoza.com)

1. What are the current practices used to educate teachers to teach statistics in different countries? What is promising and what is weak about these practices?

2. What are successful examples of programmes that help teachers develop statistical knowledge and teaching competencies? What evidence exists of good didactic situations that are meaningful to teachers and can be used to educate teachers to teach statistics?

3. What examples are there of learning experiences for preservice teachers that help them construct an overall appreciation of the "big ideas" in statistics and how they are taught?

4. How can technology use be maximized to support teachers' statistical learning?

5. Which materials are currently available to teachers to help them increase their knowledge and competence in relationship to the teaching of statistics?

6. What kinds of professional development opportunities do teachers have while teaching statistics?

TOPIC 4. *Empowering teachers to teach statistics: A look into the future.*

Organisers: Joachim Engel (engel@ph-ludwigsburg.de) and Maxine Pfannkuch (pfannkuc@math.auckland.ac.nz)

1. What challenges do teachers face and what support do they need when teaching statistics?

2. What is the theoretical basis for teacher learning in statistics?

3. What practice-based learning in statistics is essential for in-service and pre-service teachers? What case studies collected from school practice help in the education of teachers?

4. How can teachers be prepared to deal with appropriate context knowledge when applying their statistics teaching to a diverse range of applications?

5. How can teachers be enabled to create an instructional design that allows students to acquire the basic ideas of statistics?

6. What statistical technology experiences are essential for teachers? How can the learning of statistics, through using technology, be integrated into every teacher's experience? How much knowledge do teachers need about multimedia learning in order to take advantage of modern technology for designing instruction in statistics? How much knowledge is needed about empirical and experimental methods such as simulations?

7. How can teachers acquire a sufficient level of statistical literacy? How much critical competency in reading and evaluating statistically based reports in media (e.g., newspapers, TV, Internet, ...) do they need?

8. How does current research help in understanding good teachers' practice (or training programs) in statistics education? What new research is needed to assist preparing teachers to teach statistics at the school level?

TOPIC 5. *Training teachers in developing countries.*

Organisers: Jun Li (lijun@math.ecnu.edu.cn) and Victor Polaki (mv.polaki@nul.ls)

1. What are the challenges and prospects of preparing statistics teachers in the developing world where the infrastructure is generally poor, where useful technologies such as calculators and computers may be available but not affordable and where new statistical software is either unavailable or unaffordable even in situations where computers are available?

2. In the context of developing countries, how does culture impact on teachers' instructional decisions when teaching statistics? How do their beliefs, cultural norms and values, language and experience influence the teaching and learning of statistics?

3. What strategies and methods are useful for teacher training and student learning in developing countries?

4. What characteristics of developing countries might be used to support the development of statistical ideas? What might be done to ensure that statistical education does flourish even in these difficult contexts?

TOPIC 6. *Building collaboration between mathematics and statistics educators in teacher education.*

Organisers: Joan Garfield (jbg@umn.edu) and Maria Gabriella Ottaviani (mariagabriella.ottaviani@uniroma1.it)

1. What are productive models for University Faculty in different departments (mathematics education and statistics) to work together in providing pre-service coursework to prepare teachers of statistics?

2. What are productive models for statistical offices, professional statisticians in other areas and professional associations to participate in preparing teachers of statistics?

3. What are good examples of successful collaborative programs and activities for educating teachers to teach statistics?

4. What are effective ways for statisticians to help mathematicians and mathematics educators see that statistics is distinct from mathematics and that teachers need specific knowledge and training to teach statistics effectively?

5. What are effective ways to help mathematics teachers realize the importance of statistics as a discipline?

6. What are some good examples of statisticians and mathematics educators working collaboratively to find ways for statistics to be authentically integrated into the study of different mathematics topics at primary and secondary school levels?

7. What knowledge and skills do teacher educators (those who work with pre-service teachers) need in order to develop and enhance pre-service teachers' statistical thinking, reasoning and literacy?

Since research into some of the previously mentioned questions is still scarce, the Joint Study will try to encourage new research on these topics. At the same time both theoretical reflections about what such training might look like and analyses of existing successful examples of experiences in training teachers to teach statistics are welcome.

6. CALL FOR CONFERENCE PAPERS

Following tradition, this Study will comprise two parts: the Joint Study Conference[4]) and the production of the Joint Study book. The Joint Study Conference will take place at the Instituto Tecnológico y de Estudios Superiores. Monterrey, Mexico (http://www.mty.itesm.mx/), from June 30 to July 4, 2008.

Participation in the Joint Study Conference is by invitation only, based on a submitted contribution. Invitations will be based on a refereeing process[5]) to be organized by the International Program Committee with participation of experts in the different topics of the Study. Accepted papers will be presented in the Joint Study Conference and will appear in the Conference Proceedings that will be published by ICMI and IASE as a CD-ROM and on the Internet.

It is expected that participants will represent a variety of backgrounds, expertise and nationalities that will lead to a suitable coverage of the Joint Study theme, its different topics and the related questions. It is hoped that the Conference will attract mathematics and statistics educators, researchers in statistics education, practitioners in the teaching of statistics, and educators, both experienced people and young researchers entering the field.

The IPC hereby invites individuals or groups to submit contributions on specific questions, problems or issues related to the theme of the Joint Study for consideration by the Committee. Papers should represent a significant contribution to knowledge about the Study theme and be substantially different from papers that have been previously published elsewhere. Invitation to the Joint Study Conference does not imply financial support, but it is hoped this invitation will help participants get appropriate support from their own countries.

The second part of the Joint Study is the Joint Study book which will be produced after the conference and will be published in the ICMI Study Series. Participation in the conference does not automatically assure publication in the book, since a second selection and rewriting of selected papers will be made after the conference, taking into account the discussions generated by the conference.

GENERAL GUIDELINES

Papers for contributions should be submitted by e-mail no later than October 1, 2007, to the IPC Joint Study Chair (Carmen Batanero, batanero@ugr.es). Based on the results of the refereeing process the IPC will send invitations no later than January 1, 2008.

The manuscript must be written in English, the language of the conference. The maximum length is six A4 pages in single spacing, Times Roman 11 font, including references. Detailed guidelines, submission forms and other information will be available on the Joint Study Website (http://www.ugr.es/~icmi/iase_study/).

More information can be obtained from Carmen Batanero, batanero@ugr.es and Joan Garfield, jbg@umn.edu.

---

[4]) The Study Conference will merge with the 2008 IASE Round Table Conference.

[5]) The refereeing process will be double blind — identification of both authors and referees will be removed from all documentation — and will take into account the quality of the contribution, and its potential to contribute to the Study aims. All referees' comments will be returned to the authors as anonymous critiques.

7. Important dates

By 1 October 07: Potential authors send preliminary papers to the IPC Chair who will distribute them to Topic Convenors and referees. Papers received after this date will not be accepted.

By 1 January 08: Potential authors receive the result of the refereeing process. Invitations to participate in the conference are sent to authors whose preliminary papers are accepted through the refereeing process. Referees might also suggest some changes in the paper.

By 1 April 08: Invited authors send camera-ready final version of their conference papers to the IPC Chair who will distribute them to Topic Convenors and the Editor of Proceedings. Papers received after this date or that do not conform to the formatting guidelines will not be included in the Conference Proceedings.

8. International Programme Committee

Chair: Carmen Batanero (Mathematics Education, University of Granada, Faculty of Education, Campus de Cartuja, 18002 Granada, Spain, batanero@ugr.es, http://www.ugr.es/~/batanero)

Members: Bernard R. Hodgson, *ex officio, representing ICMI* (Département de mathématiques et de statistique, Université Laval, Québec, QC, Canada G1K 7P4, bhodgson@mat.ulaval.ca), Allan Rossman, *ex officio, representing IASE* (Department of Statistics, California Polytechnic State University, San Luis Obispo CA 93407, USA, arossman@calpoly.edu), Armando Albert (Mathematics Department. Instituto Tecnológico de Estudios-Superiores de Monterrey (ITESM), Campus Monterrey, Eugenio Garza Sada 2501, 64849 Monterrey, N. L., Mexico, albert@itesm.mx), Dani Ben-Zvi (Faculty of Education, University of Haifa, Mount Carmel, Haifa 31905, Israel, dbenzvi@univ.haifa.ac.il), Gail Burrill (Division of Science and Mathematics. Michigan State University, 240 Erickson, East Lansing MI 48824, USA, burrill@msu.edu), Doreen Connor (RSS Centre for Statistical Education, Nottingham Trent University, Computing & Informatics Building, Clifton Campus, Clifton Lane, Nottingham NG11 8NS, UK, doreen.connor@ntu.ac.uk), Joachim Engel (Department of Mathematics and Computer Science, University of Education, P.O. Box 220, 71634 Ludwigsburg, Germany, engel@ph-ludwigsburg.de, www.joachimengel.eu), Joan Garfield (Educational Psychology, University of Minnesota, 315 Burton Hall, 178 Pillsbury Drive, SE, Minneapolis, MN 55455, USA, jbg@umn.edu), Jun Li (Department of Mathematics, East China Normal University, 3663 Zhongshan Road (North), Shanghai, China 200062, lijun@math.ecnu.edu.cn), Maria Gabriella Ottaviani (Dip.di Statistica, Probabilità e Statistiche Applicate, University of Rome "La Sapienza", P.le A. Moro 5, 00185 Roma, Italy, mariagabriella.ottaviani@uniroma1.it), Lionel Pereira Mendoza Mathematics Education, National Institute of Education, 1 Nanyang Walk, Singapore 637616, lionel@iammendoza.com), Maxine Pfannkuch (Department of Statistics, The University of Auckland, Private Bag 92019, Auckland, New Zealand, m.pfannkuch@auckland.ac.nz), Mokaeane Victor Polaki (Department of Science Education. Faculty of Education, National University of Lesotho. P. O. Box 144, Roma 180, Lesotho, Southern Africa, mv.polaki@nul.ls), Chris Reading (SiMERR National Centre, Faculty of Education, Health and Professional Studies, Education Building, University of New England, Armidale NSW 2351, Australia, creading@une.edu.au).

REFERENCES

BATANERO, C. (2004). Statistics education as a field for research and practice. Regular Lecture at the *Tenth International Congress on Mathematical Education*, Copenhagen, Denmark.

BATANERO, C., J. D. GODINO & R. ROA. (2004). Training teachers to teach probability. *Journal of Statistics Education 12*. Retrieved August 31, 2006 from http://www.amstat.org/publications/jse/

BARBIERI, G. & P. GIACCHÉ. (2006). The worth of data: The tale of an experience for promoting and improving statistical literacy? In: A. Rossman & B. Chance (Eds.), *Proceedings of the Seventh International Conference on Teaching Statistics*. CD ROM. Salvador (Bahia), Brazil: International Association for Statistical Education and International Statistical Institute.

BEN-ZVI, D. & J. B. GARFIELD (EDS.). (2004). *The Challenge of Developing Statistical Literacy, Reasoning and Thinking*. Dordrecht, Netherlands: Kluwer.

BURRILL, G. (ED.). (2006). *NCTM 2006 Yearbook: Thinking and Reasoning with Data and Chance* (pp. 309–321). Reston, VA: NCTM.

BURRILL, G. & CAMDEN (EDS.). (2006). *Curricular Development in Statistics Education: International Association for Statistical Education 2004 Roundtable*. Voorburg, the Netherlands: International Statistical Institute. Retrieved August, 31, 2006 from http://www.stat.auckland.ac.nz/~iase/publications.php

CARDEÑOSO, J. M., P. AZCÁRATE & A. SERRADÓ. (2005). Los obstáculos en el aprendizaje del conocimiento probabilístico: Su incidencia desde los libros de texto (Obstacles in the learning of probabilistic knowledge: Influence from the textbooks). *Statistics Education Research Journal 4(2)*, 59–81. Retrieved August 31, 2006 from http://www.stat.auckland.ac.nz/~iase/publications.php?show=serjarchive

FRANKLIN, C., G. KADER, D. S. MEWBORN, J. MORENO, R. PECK, M. PERRY & R. SCHEAFFER. (2005). *A curriculum framework for K-12 statistics education*. GAISE report. American Statistical Association. Retrieved August 31, 2006 from http://www.amstat.org/education/gaise/

FRANKLIN, C. & D. MEWBORN. (2006). The statistical education of PreK-12 teachers: A shared responsibility. In: G. Burrill (Ed.), *NCTM 2006 Yearbook: Thinking and Reasoning with Data and Chance* (pp. 335–344). Reston, VA: NCTM.

FRIEL, S. N. & G. W. BRIGHT. (1998). Teach-Stat: A model for professional development and data analysis for teachers K-6. In: S. Lajoie (Ed.), *Reflections on Statistics: Learning, Teaching, and Assessment in Grades K-12* (pp. 89–117). Mahwah, NJ: Lawrence Erlbaum.

GAL, I. (2002). Adult's statistical literacy. Meanings, components, responsibilities. *International Statistical Review 70(1)*, 1–25.

GAL, I. & J. B. GARFIELD (EDS.) (1997). *The Assessment Challenge in Statistics Education*. Amsterdam: ISI and IOS Press.

GATTUSO, L. (2006). Statistics and Mathematics. Is it possible to create fruitful links? In: A. Rossman, & B. Chance (Eds.), *Proceedings of the Seventh International Conference on Teaching Statistics*. CD ROM. Salvador (Bahia), Brazil: International Association for Statistical Education and International Statistical Institute.

GATTUSO, L. & M. PANNONE. (2002). Teachers' training in a statistic teaching experimentation. In: B. Phillips (Ed.), *Proceedings of the Sixth International Conference on Teaching Statistics*, (pp. 685–692). Cape Town: International Association for Statistical Education and International Statistical Institute.

HAWKINS, A. (ED.). (1990). *Training Teachers to Teach Statistics. Proceedings of the International Statistical Institute Round Table Conference*. Voorburg, The Netherlands: International Statistical Institute.

HAWKINS, A., F. JOLLIFFE & L. GLICKMAN. (1991). *Teaching Statistical Concepts*. London: Longman.

HOLMES, P. (1980). *Teaching Statistics 11–16*. Sloug: Foulsham Educational.

JONES, J. (ED.). (2005). *Exploring Probability in Schools: Challenges for Teaching and Learning*. New York: Springer.

LAJOIE, S. (ED.). (1998). *Reflections on Statistics: Learning, Teaching, and Assessment in Grades K-12*. Mahwah, NJ: Lawrence Erlbaum.

MAKAR, K. M. & J. CONFREY. (2004). Secondary teachers' reasoning about comparing two groups. In: D. Ben-Zvi & J. Garfield (Eds.), *The Challenges of Developing Statistical Literacy, Reasoning, and Thinking* (pp. 327–352). Dordrecht, Netherlands: Kluwer.

MELETIOU, M. (2003). On the formalist view of mathematics: impact on statistics instruction and learning. In: A. Mariotti (Ed.), *Proceedings of Third European Conference in Mathematics Education*. Bellaria, Italy: European Research in Mathematics Education Society. Retrieved August 31, 2006 from http://www.dm.unipi.it/~didattica/CERME3/proceedings

MENDONÇA, T., C. COUTINHO & S. ALMOULOUD. (2006). Mathematics education and statistics education: meeting points and perspectives. In: A. Rossman & B. Chance (Eds.), *Proceedings of the Seventh International Conference on Teaching Statistics*. CD ROM. Salvador (Bahia), Brazil: International Association for Statistical Education and International Statistical Institute.

MICKELSON, W. T. & R. HEATON. (2004). Primary teachers' statistical reasoning about data. In: D. Ben-Zvi & J. Garfield (Eds.), *The Challenges of Developing Statistical Literacy, Reasoning, and Thinking* (pp. 353–373). Dordrecht, Netherlands: Kluwer.

MONCECCHI, G. & M. P. D'ARGENZIO. (1994). Textbooks and statistics in Italian primary school. In: L.Brunelli., G. Cicchitelli (Eds.), *Proceedings of the First Scientific Meeting of the International Association for Statistical Education* (pp. 23–24). Perugia: International Association for Statistical Education.

NCTM. (2000). *Principles and standards for school mathematics*. Reston, VA; NCTM. Retrieved August 31, 2006 from http://standards.nctm.org/

OTTAVIANI, M. G. & S. RIGATTI. (2005). "Data and predictions" emerging as one of the basic themes in the mathematical curriculum of the first cycle school level in Italy. In: G. Burrill, & M. Camden (Eds.), *Curricular Development in Statistics Education: International Association for Statistical Education 2004 Roundtable*. Voorburg, the Netherlands: International Statistical Institute. Retrieved August, 31, 2006 from http://www.stat.auckland.ac.nz/~iase/publications.php

PEREIRA-MENDOZA, L. (ED.). (1993). *Introducing Data Analysis Into Schools: Who Should Teach it and How? Proceedings of the International Statistical Institute*

Round Table Conference. Voorburg, The Netherlands: International Statistical Institute.

RUBIN, A., & A. S. ROSEBERY. (1990). Teachers' misunderstandings in statistical reasoning: Evidence from a field test of innovative materials. In: A. Hawkins (Ed.), *Training Teachers to Teach Statistics. Proceedings of the International Statistical Institute Round Table Conference* (pp. 72–89). Voorburg, The Netherlands: International Statistical Institute.

RUSSELL, S. (1990). Issues in training teachers to teach statistics in the elementary school: A world of uncertainty. In: A. Hawkins (Ed.), *Training Teachers to Teach Statistics Proceedings of the International Statistical Institute Round Table Conference* (pp. 59–71). Voorburg, Netherlands: International Statistical Institute.

SCHEAFFER, R. L. (2006). Statistics and mathematics: On making a happy marriage. In: G. Burrill (Ed.), *NCTM 2006 Yearbook: Thinking and Reasoning with Data and Chance* (pp. 309–321). Reston, VA: NCTM.

SEDLMEIER, P. (1999). *Improving Statistical Reasoning. Theoretical Models and Practical Implications*. Mahwah, NJ: Erlbaum.

SEP. (2006). *Programa de estudio, educación secundaria* (Curricular guidelines for secondary education) Dirección General de Desarrollo Curricular de la Subsecretaría de Educación Básica de la Secretaría de Educación Pública, México.

SHAUGHNESSY, J. M. (1992). Research in probability and statistics: Reflections and directions. In: D. A. Grouws (Ed.), *Handbook of Research on Mathematics Teaching and Learning* (pp. 465–494). New York: Macmillan.

—— (2006). Research on students' understanding of some big concepts in statistics. In: G. Burrill (Ed.), *NCTM 2006 Yearbook: Thinking and Reasoning with Data and Chance* (pp. 77–95). Reston, VA: NCTM.

—— (In press). Research on statistics learning and reasoning. In: F. Lester (Ed.), *Second Handbook of Research on Mathematics Teaching and Learning*. Greenwich, CT: Information Age Publishing, Inc., and NCTM.

SHAUGHNESSY, J. M., J. GARFIELD & B. GREER. (1996). Data handling. In: A. Bishop et al. (Eds.), *International Handbook of Mathematics Education* (v. 1, pp. 205–237). Dordrecht, Netherlands: Kluwer.

STOHL, H. (2005). Probability in teacher education and development. In: G. Jones (Ed.). *Exploring Probability in Schools: Challenges for Teaching and Learning*. New York: Springer.

VERE-JONES, D. (1995). The coming of age of statistical education. *International Statistical Review 63(1)*, 3–23.

WALLMAN, K. K. (1993). Enhancing statistical literacy: Enriching our society. *Journal of the American Statistical Association 88*, 1–8.

WATSON, J. M. (1998). Professional development for teachers of probability and statistics: Into an era of technology. *International Statistical Review 66*, 271–289.

—— (2001). Profiling teachers' competence and confidence to teach particular mathematics topics: The case of data and chance. *Journal of Mathematics Teacher Education 4*, 305–337.

WILD, C. & M. PFANNKUCH. (1999). Statistical thinking in empirical enquiry. *International Statistical Review 67(3)*, 221–248.