



## Discussion Document

### 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 foundation in 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 and suggest some preliminary research questions,

### 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 of them 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 of only 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 teachers responsible for teaching statistics, 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 always be applied (Russell, 1990; Batanero, Godino & Roa, 2004)<sup>1</sup>. 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). In most settings, little opportunity for teachers' professional development in statistics exists, even in applying statistics to analyse educational data. As a consequence, teachers have no support for further professional development in statistics (Watson, 2001; Gattuso & Pannone, 2002; Mendonça, Coutinho & Almouloud, 2006) or may 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 focussed on the education and professional development of teachers to teach statistics (Shaughnessy, 2007).

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<sup>1</sup> 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.

### *Specificity of statistics education*

The above problems do not just concern 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 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 still being debated within statistics and its applications, which does not happen in other areas of mathematics. Statistics is much more closely related than mathematics to other sciences (from linguistics or geography to physics, engineering or economy) 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).

Statistics is separate today 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, 2007). Moreover, there has recently been a large increase in statistics education research outside the mathematics education community<sup>2</sup>. 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).

### 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 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 will consider the specificity of statistics teaching at the school level and teachers' statistical learning and will provide an overall picture of the current situation in both

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<sup>2</sup> 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 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 recommendations and materials that can be used in the training of both prospective teachers at the 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 describing 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 focussing 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 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).

#### AUDIENCE AND POTENTIAL PARTICIPANTS

We hope the Joint Study results will 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 inter-disciplinary 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 educators with different levels of experience, including people who are well known in the area, new researchers who are just forming their views, and teacher trainers responsible for training future mathematics teachers who will be delivering statistics at school levels.

#### 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 questions around each topic that served as an initial focus for potential papers and can 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. Organizers: 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 to be able to develop statistical concepts and inquiry in their students?<sup>3</sup> 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?*
  - *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@iamendoza.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?*

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<sup>3</sup> 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?

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 the 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 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 students learning statistics 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 to provide 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 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 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 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.

#### CALL FOR CONFERENCE PAPERS

Following tradition, this Study will comprise two parts: the Joint Study Conference<sup>4</sup> 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 only by invitation, based on a submitted contribution. Invitations will be based on

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<sup>4</sup> The Study Conference will merge with the 2008 IASE Round Table Conference.

a refereeing process<sup>5</sup> 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 participation 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.

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<sup>5</sup> 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.



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