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Carmen Batanero
Gail Burrill
Chris Reading *Editors*

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

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Editors

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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 the of production of the book.

Carmen Batanero — Universidad de Granada, Spain
Gail Burrill — Michigan State University, USA
Chris Reading — University of New England, Australia

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Part I
Global Perspective

Gail Burrill

Chapters presented in this part are organised into two sections, each composed of short chapters that present examples of how the teaching of statistics is conceived in different curriculum around the world (Chaps. 1–4) and how teachers are trained to teach statistics at school level in different countries (Chaps. 5–9).

Chapters 1–4 derived from presentations in Topic 1 of the Joint Study Conference: *The current situation of teaching statistics in schools.* Presentations and discussions in this topic showed that school curricula in general are detailed, communicated and enacted in various ways among the countries of the world. Some countries have a well-defined national curriculum followed by the vast majority of school systems. Others have a curriculum on paper, but implementation is not universal. A few have no nationally mandated curriculum. The curricula for statistics share this diversity, although nearly universally, statistics is incorporated into the mathematics curriculum. Chapters 1–4 give a brief window into this diversity, with discussions of the statistics programmes in Brazil, the United States, Uganda, and South Africa. Brazil utilises statistics as a way to focus on social and political facets of society, South Africa on preparing students to be consumers of data, while in Uganda, statistics seems to be envisioned as a mathematical body of knowledge to be learned. In South Africa, national assessments drive the inclusion of statistics in the implemented curriculum, but this is not true of all countries. The use of technology in the study of statistics also differs; Brazil recommends the use of technology to minimise the tedious nature of data processing and maximise data analysis and to simulate random experiments that can help students develop an intuitive meaning of probability while in Uganda technology is not allowed at the elementary level and typically not available at other levels.

Campos, Cazorla, and Kataoka describe the statistics curriculum and methodological guidelines for implementing the objectives prescribed by the Ministry of Education

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in Brazil. The methodological guidelines position statistics as a tool for understanding the social context in which students live and suggest that statistics be considered as essential for the formation of a critical attitude on current social, political, cultural and scientific issues in the study of interdisciplinary or cross-cutting themes.

In contrast, at the time of the study, the United States had no national curriculum, with each state responsible for its own mathematics and statistics standards. Newton, Dietiker, and Horvath report on an analysis of the standards from 41 states about the role of statistical reasoning and the statistical process. The findings suggested that procedures are overemphasised in the curricular expectations as defined by the standards (particularly in the lower grades) with little expectation that the curriculum encourage statistical reasoning.

Uganda has a compulsory curriculum, but according to Opolot-Okurut and Opyene-Elu the statistical content in the curriculum is mostly formula-based, and only 10% of the curriculum at the elementary level is on statistics. The focus is primarily on simple exploratory data skills; other content is optional, which, in practice, means that teachers concentrate on mathematics not on statistics. And often texts are not available, which means teachers have few resources to use in teaching statistics.

Wessels describes the revised approach to statistics in South Africa. The goals align with the goals of preparing learners for the social and economic needs they will face as adults in the twenty-first century and as consumers of interpretations of data.

Chapters 5–9 discuss the training of teachers to teach statistics and is a consequence of specific examples of courses for teacher preparation and professional development presented in the Conference Topic 3, *Analysing current practices in teacher education regarding the teaching of statistics*, while more general topics related to the training of teachers are included in Part IV. As countries increasingly are recognising the need to shift their curricula to include statistics and probability, those responsible for teaching this content are primarily teachers trained to teach mathematics. Providing appropriate preparation and professional development for teachers to teach statistics is done through programmes offered by government institutions, professional statistics associations, academic and teacher education institutions, private organisations, and in some countries, through collaborative efforts among these entities. The papers in Chaps. 5–9 include a discussion of a university-based programme in the United States, university outreach initiatives in Germany, collaborative efforts among institutions in Iran and in the Philippines, and a comparison of the training to teach statistics in Costa Rica and Panama.

Froelich describes a new curriculum in statistical content that requires the cooperation of mathematics, mathematics education, and statistics faculty for future secondary mathematics teachers at a major state university in the United State. The curriculum, however, does not focus on how to teach statistics.

According to Martignon, curricula across all states in Germany now include mandatory competencies in data analysis and statistical reasoning from elementary school to grade 12 with the focus in most states on statistical literacy. To prepare teachers to carry out these new mandates, some universities have introduced regular

seminars for future and experienced teachers on educational problems in stochastics, and some states include statistical questions on data analysis and visualisation in the central final examinations for future teachers.

The Iranian Ministry of Education designed a new course in statistics for all students in the second or third year of high school that emphasised statistical reasoning and the use of technology as a tool for analysis according to Persian and Rejali. Several professional organisations offered programmes to prepare teachers to teach this course, with much of the work initiated by the Iranian Statistical Society. Along with the Isfahan Mathematics House and the Mathematics Teachers' Society of Isfahan, they started an annual team-based statistics competition among high school students and with the help of the Iranian Statistics Research and Training Centre (ISRTC) developed an electronic site in Farsi for the popularisation of statistics.

Reston and Bersales describe examples in the Philippines of how individuals, universities, government and private organisations work together to achieve reforms. To better prepare the teachers to implement a revised school curriculum that includes some statistics and probability, the Department of Education organised a programme for elementary mathematics teachers delivered by five teacher education institutions. Two government organisations, the Philippine Statistical System and the Commission on Higher Education, collaborated with the Philippine Statistical Association to organise several reform efforts including the development and implementation of a nation-wide course in probability and statistics for teachers and the preparation of texts and reference material for teachers.

Sorto contrasts the preparation of teachers to teach statistics in two South American countries, Panama and Costa Rica reporting on opportunities to study statistics during teacher preparation programmes and in structured professional development activities in each country.

In summary, papers included in Chaps. 1–4 and 5–9 represent the variation in statistics curricula and teacher training found around the world. The examples can provide a base for comparison with situations in other countries and highlight the need to recognise the relevance of improving the statistics education of students and teachers in every country.

Chapter 1
Statistics School Curricula in Brazil

Tânia M.M. Campos, Irene M. Cazorla, and Verônica Y. Kataoka

Abstract In Brazilian basic education, National Curricular Parameters recommend the inclusion of probability and statistics as part of mathematics. Despite the innovative character and methodological guidelines focused on the formation of a scientific spirit and on civic preparation, teaching probability and statistics faces difficulties because of lack of training for teachers, didactic materials, and availability of software, among others. Therefore, statistics educators in Brazil have hard but promising work ahead.

1 Introduction

Basic education in Brazil consists of elementary and secondary education, totalling 12 years. Elementary education is comprised of two phases: the first consists of cycles 1 (6–8 year-olds) and 2 (9–10 year-olds), and the second consists of cycles 3 (11–12 year-olds) and 4 (13–14 year-olds), totalling nine grades. Secondary education consists of three grades (15–17 year-olds).

To establish content themes and their development, according to the specificities of each school level, the Ministry of Education (Ministério da Educação) prepared a document in 1997 known as the National Curricular Parameters (NCP). These parameters were developed first for application in cycles 1–2 of elementary education (Ministério da Educação, 1997), then for cycles 3–4 of elementary education (Ministério da Educação, 1998), and finally for secondary education

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(Ministério da Educação, 2002, 2006). The NCP were designed with the aim of "establishing quality goals to assist students to face the world today as participatory, reflective and independent citizens, knowledgeable of their rights and duties" (Ministério da Educação, 1997, p. 4).

This chapter presents an analysis of the mathematics in the NCP related to probability and statistics, using a methodology for content analysis (Bardin, 2006).

2 Objectives and Contents

Probability and statistics are inserted in the NCP recommendations in mathematics. In elementary education, they are part of one of the four content blocks, the "Information Handling" block. In secondary education, they are part of one of the three blocks, the "Data Analysis" block. This status shows the recognition of the importance of developing statistical reasoning in the intellectual and civic formation of students.

- The objectives of cycle 1 for elementary education are: (a) to develop procedures to collect, organise, communicate, and interpret data through tables, charts, and representations that are frequently used in daily lives; and (b) to understand that most events of everyday life are random in nature by exploring concepts of chance and uncertainty that arise intuitively in situations where the student performs experiments and observes events (Ministério da Educação, 1997).
- The objectives of cycle 2 for elementary education are: (a) to appreciate the use of statistical language as a means of communication and to facilitate ways to solve and communicate strategies and results; and (b) in the field of probability, to identify characteristics of predictable or random events from problem situations (Ministério da Educação, 1997).
- The objectives of cycle 3 for elementary education are: (a) to encourage the formulation of hypotheses from systematic observations of quantitative and qualitative aspects of reality, establishing interrelationships between those aspects (variables) by making use of mathematical knowledge, and to select, organise, and produce relevant information in order to interpret and assess those relations critically; and (b) to promote understanding of patterns and trends in data by drawing inferences from the frequencies and measures of central tendency of a population sample (Ministério da Educação, 1998).
- The objectives of cycle 4 for elementary education are: (a) to build the sample space of equally likely events by using the multiplicative principle or simulations to estimate the probability of the success of an event; and (b) to go beyond the reading of information and think more critically about the meaning in the information. Thus, the proposed topic should go beyond mere description and representation of data to include investigation of the data and decision-making based on that investigation (Ministério da Educação, 1998).
- The objectives of secondary education are: (a) to enable students to master the language of probability; (b) to raise some equiprobability hypotheses; and (c) to

associate statistics with observed results and frequencies of corresponding events and make use of such statistical frequencies to estimate the probability of a given event (Ministério da Educação, 2002, 2006).

The content suggested for the proposed objectives can be grouped under four categories, ranging in intensity and complexity as students progress through the levels of education.

- Collecting, organising, and representing data: simple and two-way tables, absolute and relative frequency; construction of bar charts, pie charts, line graphs, histograms, and frequency polygons.
- Interpreting data: for cycles 1 and 2 of elementary education, data interpretation involves essentially the reading of tables and graphs. In cycles 3 and 4 and in secondary education, in addition to reading data, students are expected to produce and interpret a number of statistical measures, including measures of central tendency (mean, median, and mode) and measures of variability (mean deviation, variance, and standard deviation).
- Drawing and assessing inferences: for cycle 4 elementary and secondary education only, drawing inferences from data analysis; using measures of central tendency and frequencies to estimate trends and probabilities.
- Understanding and applying probability and chance: notions of chance and uncertainty; probability of a single event; for cycle 4 elementary and secondary education only, building a tree diagram and using combinatorial analysis to calculate probability and conditional probability.

3 Methodological Guidelines

The formulation of hypotheses does not seem to be explicit in the objectives or content. However, the role of hypotheses becomes more evident in the methodological guidelines, where statistics is considered to be an essential tool for the formation of a critical attitude about current social, political, cultural, and scientific issues in the study of interdisciplinary or cross-cutting themes.

The guidelines also recognise the role of statistics in understanding the social context in which students live and therefore as a tool for their civic education. In relation to information reported in the media, the NCP emphasise statistics as a language to describe reality, recognising the relativity of statistical measures and how they can be handled in accordance with specific interests.

Another suggestion in the guidelines is that systematic observation of phenomena in several fields of knowledge may help students develop an investigative spirit where statistics is seen as part of the scientific method. Students should use simulation to study the regularities of phenomena, with empirical evidence needed to test hypotheses and inferences, even informally.

Finally, the NCP recommend the use of a calculator and a computer, especially spreadsheets, to minimise the tedious nature of data processing and maximise data

analysis, as well as to simulate random experiments that can help students develop an intuitive meaning of probability, observing, for example, the relative frequency of an event over a long run of repetitions.

4 Final Considerations

In conclusion, probability and statistics education in Brazil prioritises the analysis and interpretation of data where it is seen as a language to describe reality and does not emphasise the formalism of concepts and formulas. However, although the guidelines mention terms such as population and sample and use mean and frequencies as estimates of population values and probabilities, the NCP have no discussion about sampling and the variability of sample means and make no references to quantiles (except of the median) or to box plot.

The analysis conducted in this chapter may help in discussions of the NCP guidelines during the process of teacher training, assist researchers interested in the process of teaching and learning statistics, or be useful in making comparisons with the curricula from other countries.

Finally, we should mention that implementation of the NCP guidelines in schools still faces major challenges, including: (a) initial and continued preparation of teachers; (b) didactic books, which have conceptual mistakes and present the content in a fragmented way; (c) the scarcity of didactic materials; (d) research results that are not yet available to schools; and (e) the lack of free software as well as other obstacles. Taken all together, in Brazil statistics educators still have hard but promising work ahead.

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Chapter 2
Statistics Education in the United States: Statistical Reasoning and the Statistical Process

Jill Newton, Leslie Dietiker, and Aladar Horvath

Abstract Two important components of statistical literacy are statistical reasoning and the statistical process. This chapter summarises a study that analysed 41 mathematics state standards documents as they existed in 2006 to surmise the extent to which learning these components is expected of students in the United States. Most prominent among the findings were the overrepresentation of isolated statistical procedures and the corresponding scarcity of expectations addressing statistical reasoning and the statistical process.

1 Introduction

Statistical literacy has been conceptualised in many ways (e.g., Utts, 2003; Ben-Zvi & Garfield, 2004; Franklin et al., 2005); however, often highlighted as important for statistical literacy are: (a) statistical reasoning, and (b) the statistical process. Utts (2003) states that "there is less need to emphasise calculations, and more need to focus on understanding how statistical studies are conducted and interpreted" (p. 74). Similarly, Burrill and Camden (2005) propose that "students seem to be mastering statistical procedures and vocabulary but are not able to use statistical reasoning in a meaningful way" and that "an over-emphasis in school syllabi on answering questions rather than posing them, and making decisions based only on data displays produces an approach based on absoluteness of data that stifles the development of statistical thinking" (p. 4).

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The goal in the analysis described in this chapter was to report on expectations that students in the United States will use statistical reasoning and carry out the statistical process. The investigation was complicated by the fact that, unlike the majority of countries in the world, the United States does not have a national mathematics or statistics curriculum. Rather, each state has its own mathematics and statistics standards.

The analysis, then, became an examination of a set of state standards. The analysis was framed using the *Guidelines for Assessment and Instruction in Statistics Education* (*GAISE*) *Report* published in 2005 by the American Statistical Association (ASA). The *GAISE Report* proposes four process components of the statistical investigative process: (1) formulate questions, (2) collect data, (3) analyse data, and (4) interpret results (Franklin et al., 2005). These components are consistent with the data analysis standards proposed by the National Council of Teachers of Mathematics (NCTM, 2000): (1) formulate questions that can be addressed with data and collect, organise, and display relevant data to answer them; (2) select and use appropriate statistical methods to analyse data; and (3) develop and evaluate inferences and predictions that are based on data. As part of a larger study, this chapter summarises the analysis of the state standards using the four process components in the *GAISE Report* to address the following questions: (1) To what extent do the K-8 US state mathematics standards promote statistical reasoning? (2) To what extent do the K-8 US state mathematics standards expect students to carry out the statistical process?

2 Method

All of the statistics grade level expectations (GLEs) from 41 state standards documents were collected, and each GLE was coded into the appropriate process component (Franklin et al., 2005):

1. Formulate questions: (a) clarify the problem at hand; (b) formulate one (or more) questions that can be answered with data;
2. Collect data: (a) design a plan to collect appropriate data; (b) employ the plan to collect the data;
3. Analyse data: (a) select appropriate graphical and numerical methods; (b) use these methods to analyse the data; and
4. Interpret results: (a) interpret the analysis; (b) relate the interpretation to the original question.

Many GLEs were coded as applicable for more than one process component. For example, third graders in South Dakota are expected to "gather data and use information to complete a scaled and labelled graph". This GLE was coded as both Collect Data and Analyse Data. Expectations for statistical reasoning within each process component and expectations related to conducting the statistical process were noted.

3 Results and Discussion

General findings. In the 41 state standards documents, as they existed in 2006, 1,711 GLEs address at least one of the four process components (approximately 42 statistics GLEs per state). Across all states, the number of GLEs increases steadily from Kindergarten (98 GLEs) until grade 7 (244 GLEs), and then decreases slightly in grade 8. Table 2.1 summarises the number of GLEs coded into each process component. Results show that students are much more often expected to analyse data and interpret results than to formulate questions and collect data.

Statistical reasoning. When students were expected to go beyond statistical procedures to evaluate or reflect on these procedures, the GLE was coded as statistical reasoning. For example, sixth graders in Florida are expected to "find the range, mean, median, and mode of a set of data". GLEs of this type do not seem to require statistical reasoning. In contrast, eighth graders in Michigan are expected to "recognise practices of collecting and displaying data that may bias the presentation or analysis". Some GLEs expected both doing procedures and reasoning statistically. For example, seventh graders in Washington are expected to "formulate a question and collect data from a population, describing how the questions, collection method, and sample population affect the results". Forty of the 41 states analysed include at least one GLE that promotes statistical reasoning. Table 2.2 summarises the relative frequencies of GLEs that promote statistical reasoning across the process components.

Only 28% of the GLEs across the 41 states promote statistical reasoning. In addition, expectations for statistical reasoning were much more prevalent in GLEs addressing data collection and analysis than in question formulation and interpretation of results. The frequency of GLEs that promote statistical reasoning increases from four GLEs in Kindergarten to 113 GLEs in Grade 8, indicating that young students are expected to do little statistical reasoning.

Table 2.1 Number of grade level expectations (GLEs) by process component

	Formulate questions	Collect data	Analyse data	Interpret results	Overall
Number of GLEs	12	423	968	867	1,711

Table 2.2 Frequency of statistical reasoning grade level expectations (GLEs)

GLE	Formulate questions	Collect data	Analyse data	Interpret results	Overall
Promotes statistical reasoning	13	119	325	66	475
Includes process component	112	423	968	867	1,711
Percent of process component GLEs requiring statistical reasoning	12%	28%	34%	8%	28%

Statistical process. Only 41 of the 1,711 GLEs (approximately 2%) include the expectation that students plan and carry out the statistical process. For example, third graders in the Department of Defense schools are expected to "develop and implement a plan to collect and organise data to address a given question". However, some GLEs include several process components that may indicate the state's expectation that students move beyond isolated process components. For example, third graders in Oklahoma are expected to "pose questions, collect, record, and interpret data to help answer questions". This GLE expects students to carry out the statistical process from beginning to end (i.e., includes all four process components). Less than 30% of the GLEs include more than one process component in a single GLE, and only 7% of the total include three or four process components. However, nearly half of the states either address study design explicitly or combine all four process components into one GLE suggesting that students should carry out the entire statistical process. In addition, 15 GLEs address the iterative nature of the statistical process. For example, sixth graders in Tennessee are expected to "make conjectures to formulate new questions for future studies".

4 Conclusion

The study set out to determine whether K-8 state standards in the United States of America promote statistical reasoning and expect students to conduct the statistical process. In both cases, the answer is that most states do but to a very limited extent. The procedures associated with the statistical process are undoubtedly an important part of statistical knowledge; however, this analysis indicates that there is an overemphasis on these procedures (particularly in the lower grades) and a lack of expectation that the curriculum should go beyond these procedures to encourage statistical reasoning.

Several important implications for teacher education programmes emerge from this analysis. First, a holistic approach to the statistical process is needed in order for teachers to understand the importance of spending time assisting students with question formulation and data collection (this analysis found these process components to be underrepresented in the state standards). Second, teachers will need to be prepared to facilitate discussions with students around the expectations that promote statistical reasoning. That is, in many states (to varying degrees), statistics education has moved beyond calculating means and constructing graphs, and it is important that teachers know how to implement these new expectations. Finally, it seems important that teachers begin to see state expectations as a minimum requirement. That is, teachers working in states that expect students only to "do" the process components and that lack attention to statistical reasoning and/or the statistical process should be encouraged to enhance their instruction to include these critical components of statistical literacy.

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