

## *Appendix 2: Paper Abstracts and Roundtable Discussion Questions*

### *Curriculum Perspectives and Statistics Education*

#### *Paper 1: Statistics Curriculum and Development: New Ways of Working*

Andy Begg, University of Auckland, New Zealand/Open University, United Kingdom

##### *Abstract*

Curriculum has often been developed without due consideration of what curriculum means, or ways in which it is developed. To help with this I explore the meanings of curriculum and development, critique the present method of curriculum development, present an alternative model, consider the inter-related activities from the model, and discuss some influences on development. Finally I look at some implications for curriculum in the future.

##### *Discussion Questions:*

1. How can international groups such as IASE recognize and best contribute to the development of statistics education internationally?
2. How can international groups such as IASE make visible the complexity of curriculum development for teaching and learning statistics?
3. How can we best develop curriculum resources at an international level and ensure that local people, especially teachers, are involved in the development and modification of these resources?
4. (Curriculum resources could mean discussion papers about statistics and the development process, statements of aims, mappings of the big ideas of statistics and ideas related to them, or exemplars of rich statistical learning activities and assessment activities.)
5. How can we encourage the recognition of diversity as of value in the curriculum process while at the same time producing ideal guidelines?

#### *Paper 2: Directed Self-explanation in the Study of Statistics*

Nick Broers, Maastricht University, The Netherlands

Marieke Mur, Maastricht University, The Netherlands

Luc Budé, Maastricht University, The Netherlands

##### *Abstract*

Constructivist learning theory has suggested that students can only obtain conceptual understanding of a knowledge domain by actively trying to integrate new concepts and ideas into their existing knowledge framework. In practice, this means that students will have to explain novel ideas, concepts and principles to themselves. Various methods have been developed that aim to stimulate the student to self-explain. In this study, two such methods were contrasted in a randomized experiment. In one condition students were stimulated to self-explain in an undirected way, in the other, the stimulus to self-explain was directed. We examined whether the directive method leads to a greater level of conceptual understanding. To assess conceptual understanding students were asked to construct a concept map and to take a 10-item multiple-choice test. The results are somewhat contradictory but do suggest that the directive method may be of value. We discuss the possibility of integrating that method in the statistics curriculum.

##### *Discussion Questions:*

1. In what way does conceptual understanding differ from learning goals for statistical literacy, statistical reasoning, and statistical thinking? Could it be considered as more basic or elementary, maybe as a necessary prerequisite to the other learning goals?

2. What promise does the method for stimulating directed self-explanation, as described in the paper, hold for helping students to attain conceptual understanding of the material?
3. If the method can be considered as promising, how could it be implemented in the statistics curriculum?

*Paper 3: Consideration of Variation: A Model for Curriculum Development*

Chris Reading, University of New England, Australia  
Jackie Reid, University of New England, Australia

*Abstract*

Consideration of variation has been identified as one of the fundamental types of statistical thinking and recent research into the understanding of variation highlights its growing importance. Curriculum needs to reflect this trend. This report proposes a model for an integrated approach to curriculum development where consideration of variation is used as the linking thread. The application of this process to a tertiary introductory service statistics course is presented. A hierarchy of levels of consideration of variation is developed from students' responses to 'minute papers'. Typical responses in the various levels of the hierarchy are discussed. The hierarchy can be used to evaluate the effectiveness of the integration of variation into the curriculum. This research has implications for teachers of statistics in the development of curriculum and also implications for researchers in the growing field of students' understanding of statistics.

*Discussion Questions:*

1. How can students be helped to develop a more holistic view of curriculum content?
2. Our report deals with an integrated approach to curriculum to assist students to develop a holistic view. What else could be done to aid students in developing this holistic view?
3. What threads can be used to integrate the topics within the curriculum?
4. The integrated approach taken in the course in our report was to use *Consideration of Variation*, one of the Wild and Pfannkuch (1999) Fundamental Types of Statistical Thinking, as the thread. What other threads could be used to integrate the curriculum?
5. How else can the success of this integrated approach to developing curriculum be evaluated?
6. The level of consideration of variation evidenced in students' responses to in-class tasks was used in this research as a measure of the success of the integration, based on consideration of variation, of the content. Thus the learning demonstrated by the students in the integrating thread has been used to evaluate the approach. What other methods might be useful for evaluating this integrated approach to curriculum?

*Paper 4: Statistical Literacy Curriculum Design*

Milo Schield. Augsburg College, Minneapolis, MN, USA

*Abstract*

The goal is to design a statistical literacy curriculum for the 40 percent of college students in majors that don't require statistics or mathematics. This paper finds that key topics in conditional probability, multivariate regression and the vulnerability of statistical significance to confounding must be included, suggests that their omission may be due to the lack of appropriate teaching tools, and presents some new ways to teach these ideas based on field trials in the W. M. Keck Statistical Literacy project at Augsburg College. Humanities majors see value in this approach based on arguments, observational studies, natural language and graphs. Statistical educators should work together to refine this critical thinking approach to statistical literacy.

### *Discussion Questions:*

1. Should statistical educators support a college-wide QR requirement for graduation?
2. Should statistical educators support a wide variety of introductory courses?
3. Should statistical educators support a graph and language based statistical literacy course for students in majors such as the humanities that don't require a math or stat course?
4. Should statistical educators support a stronger focus on confounding in the regular introductory courses?

### *Discussants: Curriculum and Perspectives on Statistics*

Carol Blumberg & Sean McCusker

- How do we help the world understand that statistics education is vital in a world where social policy, technology, environment, etc. all depend strongly on careful design of investigations and very fine analysis of data?

### *Curricular Approaches in Teaching Statistics*

#### *Paper 1: Uncovering and Developing Student Statistical Competences via New Interfaces*

James Ridgway, University of Durham, UK  
Sean McCusker, University of Durham, UK  
James Nicholson, Belfast Royal Academy, UK

#### *Abstract*

The paper reviews the nature of statistics in the UK National Curriculum. While there is great opportunity for statistics to inform thinking in a range of disciplines, there is little coherence in the planning of activities for children. Formal assessment of statistical ability focuses on procedural knowledge, applied to univariate and bivariate problems. These provisions are inadequate for informed citizenship. We report work on World Class Tests, where students aged 9 and 13 years are presented with both paper-based and IT-based problem solving tasks in mathematics and science. Many of these tasks require students to work with three or more variables, often non-linearly related to each other. Students perform rather well on these tasks. Tasks are shown, together with performance data disaggregated by school and sex. Features of the displays that make them well suited to the exploration of complex patterns are discussed, and our design principles are described. Our current activities set out to embed test items in curriculum materials suitable for use in mathematics and science classrooms. A good grounding in handling complex data is essential for informed citizenship; we are in the process of developing powerful methods to help students develop appropriate skills

#### *Paper 2: Integrating Technologically-Based Laboratory Modules into the Stochastic Processes Curriculum*

Timothy Matis, New Mexico State University, USA  
Linda Ann Riley, New Mexico State University, USA  
James Matis, Texas A&M University, USA

#### *Abstract*

This paper describes a new and innovative approach to the instruction of applied stochastic processes at institutions of higher education and a method for introducing this topic to K-12 students for pre-course motivation. This approach consists of incorporating laboratory modules via digital video media that present real-world applications of stochastic processes into coursework. The modules engage the students in problem solving, thereby creating a conceptual framework for learning the subject. The pedagogy behind this instructional approach and module content is described in this paper. Preliminary

evaluations are presented for assessment purposes from a pilot implementation of the modules at the collegiate level.

*Discussion Questions:*

1. What other pedagogical approaches to learning may be used in a similar technological laboratory environment for the instruction of stochastic processes?
2. Are there other topics (applications) for the modules that may be particularly effective for student learning?
3. Are there other established approaches to the instruction of stochastic processes that focus on the application of the subject?

*Paper 3: A Data-Oriented Active Learning, Post-Calculus Introduction to Statistical Concepts, Methods, and Theory*

Allan Rossman, California Polytechnic State University, San Luis Obispo, CA, USA

Beth Chance, California Polytechnic State University, San Luis Obispo, CA, USA

*Abstract*

The paper describes a project to develop curricular materials for a course that introduces students at the post-calculus level to statistical concepts, methods, and theory. This course provides a more balanced introduction to the discipline of statistics than the standard sequence in probability and mathematical statistics. The materials incorporate many features of successful statistics education projects that target less mathematically prepared students. The student audiences targeted by this project are particularly important because they have been overlooked by previous curricular reform projects. Most importantly, the proposed audience includes prospective teachers of statistics, introducing them to content and pedagogy that prepare them for implementing NCTM Standards with regard to statistics and probability and for teaching the Advanced Placement course in Statistics.

*Discussion Questions:*

1. Do other countries see a need for a data oriented active learning course, which aims to offer a more balanced introduction to the discipline for mathematically inclined students?
2. Does such a course appear to be addressing a need for preparing future teachers of statistics? Would it appear to be helpful in addressing this need in other countries as well?
3. Is there support or prioritization for the guiding principles of the development of these materials? Do the sample activities/materials appear to adhere to these guiding principles?

*Discussants: Curricular Approaches*

Jean Claude Girard & Chris Reading

- What is important to teach? When should it be taught and how?
- How do we carefully structure the curriculum?

Content Issues Related to Teaching and Learning Statistics

*Paper 1: Statistical Literacy: From Idiosyncratic to Critical Thinking*

Jane Watson, University of Tasmania, Australia  
Rosemary Callingham, University of New England, Australia

*Abstract*

This paper follows earlier research using a survey instrument devised to measure statistical literacy understanding at the school level. Based on partial credit Rasch analysis, the performance of 673 students in Grades 5 to 10 is reported both overall and for three subgroups of items reflecting strands within statistical understanding. The three strands are the basic measurement of average and chance, the related ideas of sampling and inference, and the representation of data and variation. A hierarchy of six levels of understanding is presented, with differing trends across the grades discussed and an example of individual student performance at each level given. Some of these examples illustrate student differences in understanding for the different strands. Implications for the school curriculum are considered with respect to potential development across the years of schooling and realistic expectations for students at various grade levels. Issues for further consideration and research are raised in the final section.

*Discussion Questions:*

1. What is the appropriate curriculum balance between context and statistical skills, and what are the implications for teachers?
2. Given the differential patterns of performance between high and low ability students, and across grades, what are some reasons for this and what implications are there for the middle school curriculum?
3. Given that this study was carried out in one school system in one country, to what extent would the findings be likely to be reproduced in other countries, and other educational contexts?

*Paper 2: Should Young Students Learn About Box Plots?*

Arthur Bakker, Utrecht University, The Netherlands  
Cliff Konold, University of Massachusetts, USA  
Rolf Biehler, University Kassel, Germany

*Abstract*

In this paper, we explore the challenges of learning about box plots and question the rationale for introducing box plots to middle school students (up to 14 years old). Box plots are very valuable tools for data analysis and for those who know how to interpret them. Research has shown, however, that some of their features make them particularly difficult for young students to use in authentic contexts. These include that box plots generally do not allow perceiving individual cases; box plots operate differently than other displays students encounter; the median is not as intuitive to students as we once suspected; quartiles divide the data into groups in ways that few students (or even teachers) really understand. As a result, we recommend that educators consider these features as they determine whether, how, and when to introduce box plot to students.

*Discussion Questions:*

1. What principles should we use in deciding when to introduce students to particular statistical ideas or representations?
2. What tools or representations would help students not only notice variability but begin to quantify it?
3. What are your experiences with introducing box plots?

### *Paper 3: Within, Between, and Beyond*

Anthony Harradine, Noel Baker Centre for School Mathematics, Australia

#### *Abstract*

IASE Roundtable organizing committee (2004) talks about people making ‘reasoned decisions based on sound statistical thinking’. As a string of seven words it rolls easily off one’s tongue; as an outcome, however, it remains elusive. This paper looks at the journey (and output) of one school, from 1997 to 2004, taken in an effort to empower its students to make reasoned decisions based on sound statistical thinking. Background reasons for the journey will be outlined, and general description and critical comment of some of the learning experiences used will be given. The last twelve months of the journey will be considered in some detail. We discuss six phases of teaching and learning that may assist in the realization of the goal of reasoned decision-making based on sound statistical thinking. Complementing the phases is a preliminary approach to data analysis called *distribution division*. The effects of this approach on the middle school curriculum will also be discussed.

#### *Discussion Questions:*

1. Is there a level of exploring data below the presently accepted entry level? That is, do tools exist that pre-date the use of mean, median, IQR and so on, the use of which allow students to gain a sufficient picture of the data to argue difference or similarity between two groups?
2. What experiences develop students’ ability to read beyond the sample data they have to conjecture about the population from which the data came? How can we strengthen their desires to make conjectures and use phrases like "the data tends to support the conjecture that ..."

### *Paper 4: Curriculum Innovations Based on Census Microdata: A Meeting of Statistics, Mathematics, and Social Sciences*

William Finzer, KCP Technologies, Emeryville, CA, USA  
Tim Erickson, Epistemological Engineering. Oakland, CA, USA

#### *Abstract*

Mathematics curriculum materials for early secondary school, based on interactive exploration of the huge database of individuals who filled out the “long” form for the US Census back through 1850, illustrate methods for improving statistical literacy and mathematics conceptual understanding while immersing students in social science content.

#### *Discussion Questions:*

1. Some might object that US Census microdata provide such an overwhelming context that ninth graders will (mostly) drown rather than be able to learn to swim. What is your opinion?
2. Imagine that you have the kind of interactive access to census microdata described here for the country in which you live. Would you make use of this access in your situation?
3. How can we create curriculum materials that support open-endedness and student autonomy at the same time recognizing the need to give clear instructions to students and teachers about what to do next?

#### *Discussants: Content Issues*

Roxy Peck & Gilbert Schuyten

- What do we know about when concepts should be taught and how?
- How can we make statistics education more inviting?

## Statistics Education Research and Implications for Teaching

### *Paper 1: Developing Statistical Thinking in a Secondary School: Drawing Conclusions from Data*

Pfannkuch, Maxine, The University of Auckland  
Julia Horring, Auckland Girls' Grammar School, New Zealand

#### *Abstract*

This paper describes the first year of a three-year collaborative curriculum development project in a secondary school that is underpinned by a theoretical statistical thinking framework. The teachers developed and implemented the statistics unit for their Year 11 (15 year-olds) classes based on their understanding of the framework and within the constraints of the national curriculum and assessment. Data gathered on the development of the statistics unit and its subsequent implementation are presented and discussed. An initial finding was that teachers were able to begin changing their practice to foster students' statistical thinking that was consonant with the framework. The influences of the framework, identifying problematic situations, collaboration, and assessment, which are impinging on the curriculum development, are elaborated upon and questions are raised about the nature of the development.

#### *Discussion Questions:*

1. A collaborative curriculum development between a researcher and teachers would seem to produce some desirable teaching outcomes. How can such a learning environment be created so that all teachers in schools can experience, learn, and understand other ways of teaching statistics?
2. What system processes need to be created to allow opportunities for all teachers to actively participate in statistics curriculum development?

### *Paper 2: Statistics Education for Junior High School in China*

Jun Li, East China Normal University, China

#### *Abstract*

The Ministry of Education of China is pushing a reform to include statistics and probability in its national elementary and secondary curriculum. The new Standards, Standards-based textbooks and some preliminary feedback from teachers will be illustrated in this paper.

#### *Discussion Questions:*

1. What is the role of texts in improving teachers' teaching?  
Here, texts means printed textbooks, hypertexts in electronic devices that can be read as texts, such as CD ROMs, web-based educational products, etc., and teaching and learning materials, such as resources books, problem booklets, workbooks, other teachers' lesson plans, etc.
2. How can we make use of research results in statistics education, especially the studies on students' cognition development?

### *Paper 3: Coherent and Purposeful Development in Statistics across the Educational Spectrum*

Helen MacGillivray, University of Technology, Queensland, Australia

#### *Abstract*

A combination of circumstances has enabled simultaneous observation over almost a decade of a range of statistical issues in curriculum across school levels in an Australian state and across many disciplines at the tertiary level. This paper combines a cross-sectional report on interaction with teachers

in the development and implementation of school syllabuses, with analysis of commonalities in cross-disciplinary tertiary student learning in introductory data analysis subjects. The study uses these contexts to demonstrate the need and potential for collaborative strategies to contribute to coherent and purposeful progression in the development of statistical literacy and thinking, with improved support for teachers and improved statistical learning in a range of disciplines.

*Discussion Questions:*

1. What are the best strategies, locally and internationally, to achieve sufficient influence in curricular development and implementation, including teacher support and professional development, across the educational spectrum?
2. To what extent do we need to identify whether misconceptions arise “naturally” or from educational conditions, or should we place the major focus on preventative and remedial measures in curriculum development?
3. What are the best strategies for collaboration with the development of mathematical literacy/numeracy?

*Paper 4: Preparing Secondary Mathematics Educators to Teach Statistics*

Robert Gould, University of California at Los Angeles  
Roxy Peck, California Polytechnic State University, San Luis Obispo, CA, USA

*Abstract*

This paper addresses the Roundtable topics of developing teachers' statistical knowledge and of distance education. We describe a new professional development program for secondary mathematics teachers who are preparing to teach statistics, and address what we have learned in our efforts to design a course that has a significant online component and that is relevant and useful from a teacher's perspective. The ways in which our online environment incorporates group work, self-study, exploration of concepts, and assessments are described. The challenges associated with delivering the necessary content while at the same time recognizing the practical time constraints of adult students who are themselves teaching full-time are also discussed.

*Discussion Questions:*

1. Are distance learning methods suitable (effective, efficient, possible) for teaching beginning statistics teachers?
2. How can one effectively encourage group work in a distance setting? Does collaborative work have the same pedagogical appeal in this setting as it does in the standard classroom setting?
3. What existing technologies can best implement an online statistics course?

*Discussants: Statistics Education Research and Implications for Teaching*

Jane Watson & Arthur Bakker

- What do we know and what do we need to know?
- How does research link to practice?

*Policy Decisions and Implications for Curriculum Implementation*

*Paper 1: "Data and Predictions" Emerging as One of the Basic Themes in the Mathematical Curriculum of the First Cycle School Level in Italy*

Maria Gabriella Ottaviani, University of Rome, La Sapienza, Italy  
Silio Rigatti Luchini, University of Padua, Italy

*Abstract*

The reform of the Italian school system, a new pedagogical point of view that has moved the attention from contents and skills to competences, and a new way to look after mathematics taking into consideration the globalised societal needs, have all contributed to the proposal of a new mathematical curriculum.

This paper deals with the role of the Italian Statistical Society in proposing knowledge and skills of the nucleus, "Data and predictions". The guidelines which have been followed to enhance the visibility of statistics and probability in the mathematical curriculum will be presented, taking into account the results of some recent research on statistics education in Italy.

*Discussion Questions:*

1. How can we persuade mathematics teachers of the importance of statistics as a discipline, taking account of the relation between the teachers' associations and the Education Ministry as well as the fact that in general statistics does not have a good reputation in Italian media?
2. How can we help teachers to understand the importance of statistical thinking and of the need for adequate didactical methods and didactical tools to teach the subject correctly?
3. How can we help teachers realize that an effective way to present statistics in the classroom may also have a beneficial effect on learning mathematics, as observed by some pupils reported in our paper?

*Discussants: Policy Decisions and Implications for Curriculum Implementation*

Andy Begg & Maxine Pfannkuch

- Who is responsible for developing and putting in place the curriculum?