Curricular Development in Statistics Education

International Association for Statistical Education (IASE)
Roundtable

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Preface

From 28 June to 3 July 2004 the International Association for Statistical Education (IASE) held a Roundtable on *Curricular Development in Statistics Education* in Lund, Sweden. This roundtable provided a forum for 26 participants from nine countries to consider aspects of the statistics curriculum from primary school to the tertiary level and across courses in statistics, mathematics, teacher preparation, and stochastic processes. The backdrop for the papers and discussion was:

- Research - What do we know and what do we need to know?
- Policy - Who is responsible for developing and putting in place a curriculum?
- Practice - What is important to teach, when should it be taught and how?

The papers were clustered into five sections: 1) Curriculum Perspectives and Statistics Education, 2) Curricular Approaches to Teaching Statistics, 3) Content Issues Related to Teaching and Learning Statistics, 4) Statistics Education Research and Implications for Teaching, 5) Policy Decisions and Implications for Curriculum Implementation. The discussion ranged from the development of a statistics curriculum to common issues and promising solutions to questions of how to best construct learning trajectories that will enable all students to make sense of data and to apply statistical reasoning when making decisions based on data. The conversation was framed by questions such as: How do we help the world understand that statistics education is vital in a world where social policy, technology, environment, allocation of resources depend strongly on careful design of investigations and very fine analysis of data? What topics are important to teach? When and how should the important topics be taught? How do we carefully structure the curriculum? What do we know about when and how particular concepts should be taught? How can we make statistics education more inviting? What do we know about teaching and learning statistics? What do we still need to know? How does research on statistical education link to practice? Who is responsible for developing and implementing the curriculum?

Several themes emerged from the papers presented at the Roundtable and the discussions that ensued. These are elaborated on below.

Frameworks

The role of frameworks as a guide to thinking about curriculum development in statistics, assessment, conceptual understanding, and teachers' practice is discussed from several perspectives. Andy Begg offers a general framework for curriculum development and cautions that developers should be mindful of the fact that learning is not linear. He suggests it might be more appropriate to think about curriculum as a set of cycles. Milo Shield lays out principles or central elements to guide the design of a statistical literacy curriculum for a survey course for non-majors at the tertiary level. He believes that using these principles would lead to new ways to teach concepts such as association, confounding, and statistical significance that are more in touch with the students' needs and futures.

Chris Reading and Jackie Reid describe an approach that involves the use of "minute papers" and discuss how this work relates to Maxine Pfannkuch's framework for theoretical statistical thinking. Jane Watson and Rosemary Callingham discuss their use of Pfannkuch's curricular framework in assessing statistical literacy. Using the framework, they created five levels of understanding for key content strands: 1) recognition of the need for data; 2) transnumeration (changing representations to engender understanding); 3) consideration of variation; 4) reasoning with statistical models; and 5) integrating the statistical and contextual.

Maxine Pfannkuch reports her research on how the statistical thinking framework affected teachers' practice. The goal of her work was to start teachers on a pathway toward a gradual change in their teaching, toward an approach that fosters statistical thinking. Teachers make the statistical thinking framework concrete in their instruction, and, conversely, teachers and researchers use the framework to analyze instruction. In each of these settings as well in several other papers, the case is made for beginning with a clear and well-articulated framework that could inform the development of some facet of teaching statistics and the analysis of how this development unfolds. Anthony Harradine describes six phases of teaching and learning in the progression towards the goal of reasoned decision making based on sound statistical thinking.

Statistical Thinking and Reasoning

Students seem to be mastering statistical procedures and vocabulary but are not able to use statistical reasoning in a meaningful way. This lack of students' ability to reason and think statistically is of concern in papers describing students at all levels from elementary students to those at the tertiary level. While discussing research and its implications for teaching, Helen MacGillivray comments 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. Jim Ridgway, Sean McCusker and Jim Nicholson identify this as an issue for students aged 9 to 13 years after examining assessment results and finding that top students were unable to interpret data and apply their statistical ideas in practical situations. They claim that current specifications in statistical education often focus on a rather narrow range of techniques that are applicable only to univariate and bivariate analyses. The main emphasis is primarily on the mechanical skills of constructing specified graphs correctly or "reading the graph"' to extract detailed information rather than on equipping students to become informed citizens in a society where they will be required to deal with complex data sets. As one curricular approach, Ridgway, McCusker and Nicholson describe an intervention they designed that includes a series of technology-based problem solving tasks that can be integrated into the curriculum. They also report on the design principles for such tasks that seem to be emerging from their work and on evidence showing that students – some as young as nine years old– can work with such data to reason about realistic situations and produce sensible conclusions.

While also discussing curricular approaches, James Matis, Linda Riley, and Tim Matis observe that the curriculum of many introductory courses at the collegiate level is frequently centered solely on the theoretical underpinnings of the subject, with limited exposure to its use as a tool for modeling and analysis. They observe that the subject is often illustrated with simple mathematical exercises that have no practical application or with projects that do not actively involve the students. As a consequence, they found students unable to transfer their knowledge to real contexts. To counteract this, they designed laboratory modules via digital video media that present real-world applications of stochastic processes that can be integrated into coursework. The modules engage the students in problem solving in an applied context and, as part of completing each module, ask them to deliver a comprehensive oral and written report directed towards a non-technical audience.

From a very different perspective, Allan Rossman and Beth Chance suggest that the "math stat" sequence often presents a full semester of probability before proceeding to statistics. They also suggest that in this sequence the statistics covered is often abstract in nature and does not give students a modern and balanced view of the applied as well as the theoretical aspects of the discipline of statistics. They argue that, in fact, students often leave this course with less intuition and conceptual understanding than students who have taken a lower level course (e.g., data collection issues, statistical vs. practical significance, association vs. causation, robustness, diagnostics, etc.). In response, they have developed a course to support a data-centered, active learning pedagogical style at the post-calculus level. Key features of the course materials include:

- Student-conducted investigations of statistical concepts and properties.
- Probability models introduced in the context of statistical ideas, applied to real data.
- Technology used as a tool for such techniques as simulation and to assist with graphical displays and investigating effects of parameter changes.
- Explorations of data from scientific studies, popular media, or student-collected

Assessing Understanding

Several of the papers address ways to explore and measure student understanding of statistical concepts and relate these to the curriculum. Nick Broers, Marieke Mur, and Luc Budé focus on self-explanation as a way to bring out important statistical ideas and outline a method to direct students in their self-explanation activity. Working with struggling second-year tertiary students, they found some positive results after using concept maps when they compared the results on a conventional test assessing conceptual understanding. When concept maps were used the instructor had to deconstruct the learning material of a given knowledge domain into a finite number of elementary propositions, which together cover all the relevant concepts and principles.

Watson and Callingham use a statistical literacy survey and code-book to monitor the progress of students in grades six to ten in their development of the skills required for statistical literacy. They found that most students remained at a level characterized by appropriate, but unquestioning, engagement with context, and straightforward application of statistical skills associated with the calculation of simple probabilities and means and graph reading. They argue that this finding suggest that more opportunities need to be created for students to question critically statistical claims from media sources or other real-world contexts in order to develop the analytical habits of mind that are needed to respond critically to quantitative claims.

Reading and Reid consider the degree of understanding of variation that is evident as students engage in a tertiary introductory service statistics course with “consideration of variation” as a core for the curriculum. Their work seems to suggest that the use of “minute papers” focusing on students’ understanding and reasoning, rather than merely their ability to perform calculations, can be a means of evaluating how successfully the consideration of variation thread has been used to structure the integrated curriculum.

Maria-Gabriella Ottaviani describes research in Italy demonstrating that better results may be obtained in elementary school if teachers adopt a “concept net” approach, use class interviews as tools to highlight both the individual’s and group’s knowledge, and build cognitive maps to check the progress of concept acquisition by pupils.

Jun Li describes the relation between the curriculum and assessment in Shanghai when only four out of 150 marks on the University Entrance Examinations in 1998 and 1999 were allotted to probability and none to statistics. Li also discusses how this is expected to change with the adoption of a new curriculum that includes statistics and probability.

Scaffolding the Development of Statistical Concepts

An approach with potentially significant implications for the curriculum is an emerging perspective that involves introducing central statistical concepts such as measures of center or certain graphical representations in ways that promote the development of understanding, rather than initially beginning with definitions and instruction on routine procedures.

Arthur Bakker, Rolf Biehler, and Cliff Konold describe research on promising strategies for helping students come to understand measures of center and for interpreting box plots, recommending that early instruction in statistics focus primarily, if not exclusively, on plots in which individual cases are visible. Based on their research they recommend that, when aggregate plots are introduced, the plots initially are accompanied by representations that still allow students to see individual cases. One example of representations that preserve information about individual cases involves box plots overlaid on stacked dot plots.

In his paper, Harradine suggests that problems are traditionally posed in ways that require students to read within, between, and beyond the data. That is, the student has to make comparisons between two sample data sets and then hypothesize about what that may mean about the population from which the data were drawn. He claims this is too much to ask, initially, for many students. He argues that prior to teaching standard statistical tools and procedures, students should be taught the art of “distribution division” where distributions are sliced into chunks and each chunking is considered to see what information that particular slicing configuration conveys. He also argues that the application of the skills of comparing and contrasting, and forming arguments that support a conclusion or conjecture should be taught prior to teaching standard statistical tools.

Technology

The use of instructional technology (IT) in teaching statistics has created new opportunities to present ideas dynamically and interactively to students, rather than in more conventional, ‘static’ environments. Technology use can also support the development of robust models of new sorts of conceptual learning and understanding which can underpin teaching in IT-rich environments. This was evident in the papers by Ridgway, McCusker and Nicholson; Mattis, Riley, and Mattis; Harradine; Bakker, Biehler, and Konold; and Rossman and Chance. From another perspective, technology is used both to deliver the central elements of a course and as a tool for analysis in the course. For example, Peck and Gould developed an online course for the professional development of high school statistics teachers that uses real data, active learning, and technology to teach statistics. William Finzer and Tim Erickson designed a statistical unit that can be incorporated into a course using census data obtained from a large database, where students analyze the data using Fathom Dynamic Statistics® software.

Working Groups

Roundtable participants formed working groups around central themes they identified as important in considering curriculum development in statistics education. The reports and recommendations of four of these working groups are included in this document. These reports relate to *Curriculum and Research in Statistics Education*, *The Role of Technology in Teaching and Learning Statistics*, *Statistics Curriculum: Content and Framing*, and *Teacher Preparation and Statistics Education*.

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Chair, Scientific Program Committee
IASE 2004 Roundtable on Curriculum Development in Statistics Education

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