# ONE HUNDRED YEARS OF PROGRESS – TEACHING STATISTICS 1910 – 2010: WHAT HAVE WE LEARNED? PART I: IT'S NOT MATHEMATICS BUT REAL DATA IN CONTEXT

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*In these two papers we review teaching statistics, statistical education and related outreach activities by a range of providers since the beginning of the last century. We discuss the extent and form of relevant published papers, books and conferences and give examples of where these have influenced teaching practice. In this part we show that by learning the lessons that (i) statistical and mathematical thinking are different and (ii) the goal of statistics of getting information from real data in context are both prerequisites for improving statistical literacy in people of all ages.*

## INTRODUCTION

In Part I of this two-part paper we consider lessons that had been learned by the end of the twentieth century. The history of teaching statistics has been well covered by several authors including Barnett (1982a, b), Bibby (1986), Vere-Jones (1995) and Holmes (2003). In these papers we only briefly revisit some of the history, mainly for chronological reference, and concentrate on what teachers of statistics have learned from important developments. An excellent bibliography of teaching statistics is provided by Sahai et al. (1996).

From 1885 onwards the International Statistical Institute (ISI) was generally concerned with statistical education but not systematically so until 1948 when the ISI Education Committee was set up. It is our contention that most of the key statistical education developments occurred after about 1945 - from then a series of 'Round Table' meetings took place under the umbrella of the ISI that focused on teaching and the ISI established highly influential 'task force' on secondary- and tertiary-level statistical education which published international reviews of the current states of statistical teaching at the respective levels (Barnett, 1982b; Loynes, 1987).

In the 1950s and 60s in the UK public examinations at school level included statistics for the first time. In 1952 the Royal Statistical Society published a report on teaching statistics in schools and in the 1960s they hosted two important meetings that between them considered the teaching of statistics from schools, through universities to employment with government statistical agencies.

Holmes (2003) chronicles the extent and form of the statistics taught in English schools from about 1950. He also highlights lessons that have been learned. Teachers of statistics in primary schools are very unlikely to have studied either statistics as a subject or how it should be taught. Similarly, teachers of statistics in secondary schools may only have studied a course or two in statistics within their mathematics degrees and often tend to regard and teach it as a branch of mathematics. In a report for the UK Qualifications and Curriculum Authority, Marriott et al (2007) found that many heads of mathematics and science departments in schools in England were uncomfortable with teaching even basic level statistics. At university level, teachers of statistics are frequently not located within specialist departments of mathematical sciences and many are members of other subject-specialist departments that need and apply statistics for their subject. It is our experience that university level teachers rarely consider pedagogic issues in statistics.

In the United States a Quantitative Literacy Project in the 1980s led to the development of an Advanced Placement Statistics (AP Stat) course in the 1990s. At the beginning of this century in New Zealand active participation by statisticians in curriculum development has led to the adoption (2007) of a national curriculum for Mathematics *and Statistics* (our emphasis). One of the most important events in the US was the publication of the American Statistical Association's 2005 Guidelines for Assessment and Instruction in Statistics Education (GAISE). The six key recommendations are:

In C. Reading (Ed.), *Data and context in statistics education: Towards an evidence-based society. Proceedings of the Eighth International Conference on Teaching Statistics (ICOTS8, July, 2010), Ljubljana, Slovenia.* Voorburg, The Netherlands: International Statistical Institute. www.stat.auckland.ac.nz/~iase/publications.php [© 2010 ISI/IASE]

1. emphasize statistical literacy and develop statistical thinking;
2. use real data;
3. stress conceptual understanding rather than mere knowledge of procedures;
4. foster active learning in the classroom;
5. use technology for developing conceptual understanding and analyzing data;
6. use assessments to improve and evaluate student learning.

These principles are also contained in the GAISE K-12 report by Franklin et al (2007) and in many ways nicely summarise what we think *should* have been learned in the last 100 years.

In the next section we consider what has been learned about the relationship between mathematics and statistics. In the third section we argue that we *should* have learned that using real data, relevant to learners, is crucial for the successful teaching and learning of statistics. In the fourth section we anticipate what we will consider in Part II.

## IT IS NOT ROCKET SCIENCE … OR MATHEMATICS

There was rapid development of statistical research and methodology in the early part of the 20th century, and this was generally driven by mathematics. The methodological developments were often under the auspices of biology and other subjects, in particular genetics. When statistics appeared in the Higher Education curriculum in the early part of the last century it was presented in all the glory of mathematical statistics. However, in its report on teaching statistics in schools in 1952, the RSS emphasised the importance to citizenship for individuals to have the ability to appraise charts and summary statistics. They also advocated the teaching of statistics in the context of other subjects such as natural science, geography and history (see also Holmes, 2003).

An emphasis on practical concerns in teaching statistics arose in the early 1960's at the primary school level in the UK where number work was inevitably beginning to feature simple statistical ldeas and methods. For example, Miss E.E.Biggs, one of Her Majesty's Inspectors, was 'commissioned to mobilize forces to help spread and consolidate liberal ideas on the learning of Mathematics by primary school children'. (See Barnett, 1982b, who also reviews the state at that time of teaching statistics in schools throughout the world.)

In contrast, much secondary school work in statistics was highly formal and impractical and was reflected in A-Level questions along the lines of:

*A random variable X has probability density function*

$$f(x) = k\sin(x/2) \qquad (0 \le x \le 2\pi)$$

*Determine k and the mean and variance of X*

In the late 1960's, Vic Barnett and Toby Lewis were trying to guide some schoolteachers through the minefield of preparing pupils for CGE examinations in statistics. It became clear that a consolidated effort was needed to try to bring greater practical emphasis into the teaching of secondary school statistics and ultimately in the aim of influencing curriculum content and examination syllabuses. They set up the Committee on Statistical Education (COSE), a lobby group of influential professionals from many spheres, including, schools, universities, examining boards etc. This effort eventually bore fruit in securing pioneering major funding for the Schools Council Project on Statistical Education and additional spin-off s funded projects, in establishing the journal *Teaching Statistics* and in setting up an embryonic *Centre for Statistical Education*.

The Schools Council Project on Statistical Education (POSE) was set up in the UK in 1975 and ended in 1981. The many publications that emerged from this project emphasised practical, rather than mathematical, aspects of statistics and showed how considerations of statistics pedagogy were important. Holmes (2003) reports that in a Schools Council Bulletin in 1965, Edith Biggs recommended that primary school children, not yet at an age where the mathematical aspects of statistics could sensibly be taught, should collect data for themselves and interpret graphs.

As Scheaffer (2010), one of the architects of the both the Quantitative Literacy project and the AP Statistics programme in the USA, has observed

> *Mathematical thinking (deductive reasoning) and statistical thinking (plausible reasoning) can be mutually reinforcing within a mathematics curriculum, but it is more difficult to effect than one might think. Statistical thinking is difficult to teach and learn, but it is more important than exposure to a long list of statistical methods. Formula driven approaches to teaching that emphasize a collection of methods (a toolkit) does not give students an appreciation of statistical thinking, and perhaps not even a good understanding of statistical methods.*

The AP Statistics programme emphasises statistical thinking and concepts rather than mathematical formulae and computation. This influenced the decision to include the use of technology to free students from cumbersome calculations, see Roberts et al. (1999) for more details. We agree with Nelder (1986) who has long-advocated that the words 'mathematical statistics', often used to describe courses at university, should be changed to read 'statistical mathematics'. This simple change better describes the role mathematics now has within the context of statistics.

We have learned that statistics is neither rocket science nor mathematics, rather, as Box (1996) argues, it is a branch of science. See also Cobb and Moore (1997).

## REAL RELEVANT DATA

> *It seems to me that one of the most inspiring signs of the times in education is the growing feeling–and the attempt to realise it–that when he passes under the school door, a child shall not feel as if entering into an unsympathetic, foreign world, where all is mysterious and artificial, out of which he passes periodically, with dazed ideas, only too glad to find himself once again amidst the familiar and the intelligible. We would have him, on the contrary, bring with him his outside ideas of the real world into our classroom, there to be explained and developed, thus forming a firm basis on which to build the superstructure which is to increase his understanding of that world outside the schoolroom–the world, par excellence.*

This quote, which appears to advocate child-based learning and the use of real, relevant data in the classroom, appeared in 1908 in a study of mathematical education written by a Divisional Inspector of the London County Council and is quoted in Vere-Jones (1995). He reviews the history of the Statistical Education Committee of the International Statistical Institute, from its setting up in 1948 to the establishment of the International Association of Statistical Education (IASE) in 1991. He identifies some of the underlying factors contributing to the gathering interest in and coming of age of statistical education from 1970 to 1995.

The UK Cockroft report (1982) provided an assessment of the-then state of play of teaching and learning of statistics in schools. In its paragraph 776 the report clearly stated:

> *Statistics is essentially a practical subject and its study should be based on the collection of data, wherever possible by pupils themselves.*

Other key statements from the report are:

> *Many of the ideas of which statistics makes use need time and exposure in order to mature. This means that some of the more elementary ideas should be introduced at an early stage so that understanding can develop and deepen over a period of time.*

> *Few teachers, including those whose degree or other courses have included the study of statistics, have received training in how to teach statistics in schools. There is therefore a*

> *considerable need for in-service training courses on the teaching of statistics not only for mathematics teachers but also for teachers of other subjects.*
>
> *Statistical numeracy requires a feel for numbers, an appreciation of appropriate levels of accuracy, the making of sensible estimates, a commonsense approach to the use of data in supporting an argument, the awareness of the variety of interpretation of figures, and a judicious understanding of widely used concepts such as means and percentages. All these are part of everyday living. Good statistical teaching can encourage pupils to think in these ways.*

These four statements summarised the perceptions of lessons that had been learned at the time of reporting in 1982 and therefore prefaced the activities up to the present day. The books by Anderson and Loynes (1987) on teaching practical statistics and Rouncefield and Holmes (1989) on doing practical statistics in the classroom provide good examples for getting people's hands dirty with real data production for teaching and learning statistics. There are few books that can match them for doing what they say on their covers.

In the USA activities to promote statistical education have gathered pace since the late 1980s, although Tukey (1977), Velleman and Hoaglin (1981) and other authors had for many years advocated a data-driven approach to the teaching and understanding of statistics. Burrill (1987, 1991) vigorously promoted the importance of adequate training of teachers to teach statistics and, in a series of papers Moore (1988, 1990, 1997) and several editions of an introductory level statistics book (Moore et al., 2008) advocated changes in the way statistics is taught, arguing for a more practical approach that de-mystified the subject to make it accessible to a wider range of students.

Since 1998 ICOTS have included papers that describe the efficacy of using real data to teach statistics to students of all ages. The advantages of using real data in teaching, as outlined in the GAISE report, are neatly summarised by Scheaffer (2010):

> *Learning to reason statistically must involve hands–on experience with real data, some of which should be collected by the students themselves. Active learning, more in the spirit of science laboratories than traditional mathematics classrooms, should be the standard for statistics education.*

He also recommends:

> *Random sampling in surveys and random assignment in experiments are key to obtaining data for inference, informal or formal, and these ideas must be introduced early and repeated in more and more sophisticated circumstances throughout the educational process. Statistical analysis is not a saviour for bad data.*

The sentiments expressed by Scheaffer have been repeated many times over the last 100 years and yet it is still common to find both text books and examinations, in the UK at least, that pay scant regard to real data. They generally emphasise mathematical techniques and use artificial data. There is therefore still some way to go to in communicating what many have learned, that using real data leads to real learning.

## CONCLUSIONS

We have reviewed two crucial lessons learned by the end of the twentieth century, namely that statistics has it own identity outside mathematics and that using real and relevant data is vital for the successful teaching and learning of statistics. In Part II we start just before the end of the twentieth century with the realisation that thinking of how statisticians 'do' statistics can provide important insights into how it should be taught.

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