ONE HUNDRED YEARS OF PROGRESS – TEACHING STATISTICS 1910 – 2010: WHAT HAVE WE LEARNED? PART II: PROBLEM SOLVING, PEDAGOGY AND EMPLOYEES

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In this part we consider how we have learned that statistics provides the best way to make evidence-based decisions and solve problems. From this we propose that more people should teach the subject using a problem solving approach. The emergence of a pedagogy for statistics is another key lesson. We present challenges that still exist, especially in relation to the use of statistics in employment and in the final section we bring together conclusions from both parts.

STATISTICS FOR PROBLEM SOLVING

In a discussion meeting read before the Royal Statistical Society, Hand (1998) argues that statistics is about solving real problem and that an undue emphasis on its mathematical foundations is detrimental to the discipline. Hand raises two issues, one of which we discussed in Part I. A number of other authors, for example Ehrenberg (1976) and Barnett (1986) have also emphasised that the discipline is about solving real world problems. Marriott et al (2007) argue that the lesson that statistics has a key role in solving problems should be exploited by developing pedagogy for *teaching* it through its bread-and-butter *raison d'être*, problem solving. We believe there are many advantages to be gained from teaching the discipline using a problem solving approach (PSA).

In the 1980s there was a flurry of activity concerning the teaching of statistics in a practical way. The UK POSE project published a series of 28 booklets under the title *Statistics in Your World* (see http://old.rsscse.co.uk/pose/). These were designed to help develop statistical awareness in schools through a practical approach. At a similar time in the USA, opportunities were provided for teachers to make use of practical activities and projects in their teaching through the Quantitative Literacy project. Following this, the AP Statistics Programme also made good use of projects, investigations and included planning a study in its curriculum.

In the UK the *data handling cycle*, a name used in schools for statistical problem solving, has formed part of the English national curriculum since 2000. Programmes of study published by the Qualifications and Curriculum Authority advocate using the cycle in teaching statistics within the mathematics curriculum. Marriott et al. (2009) provide some evidence for the success in teaching statistics using the PSA and provide some templates from which further teaching material can be developed. The first major text advocating the use of a problem solving approach when teaching statistics appeared in Chatfield (1988) and another early and enthusiastic advocate of changing the teaching of statistics through using a PSA is Stuart (1995). Also, it is encouraging that recently statistics textbooks that use this approach are emerging, notable among these are Stuart (2003) and Agresti and Franklin (2009).

STATISTICS PEDAGOGY

In the last twenty years many authors, for example Garfield (1995), Cobb (1992, 1993), Connor et al (2006), Watson (2006), Garfield and Ben-Zivi (2007), Zieffler et al. (2008) and the seminal paper by Moore (1997), have been concerned with exploring aspects of teaching and learning statistics. In spite of this the science of teaching statistics is not widely appreciated by teachers at all levels of statistical education even though the number of aids for teaching it has increased over the years. In particular electronic resources have proliferated since the advent of sophisticated software for *doing* statistics, examples of this are provided by Biehler (1997), delMas et al. (1999), Ben-Zivi (2007) and Darius et al. (2007). From 1948 the ISI Statistical Education Committee has been involved in the production and dissemination of teaching aids. As mentioned in part I, the POSE project produced resources for improving the teaching of statistics in schools.

In the 1980s in the USA the Quantitative Literacy project provided curriculum materials and opportunities for teachers to make heavy use of hands on activities and use projects for teaching. A one week institute for teacher continuing professional development was run during the

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summer. The American Statistical Association (ASA) established a Centre for Statistical Education which worked with science teachers to study the role of statistics in the science curriculum, and investigated the use of data analysis in the social studies curriculum in schools.

The proceedings from the series of ICOTS conferences, started in 1982 and held once every four years, contain many papers advocating innovative pedagogy for statistics. The Development Committee of the AP Statistics Programme produced teacher guides and ran teacher training workshops and conference sessions. The last three quotes from the Cockroft report, quoted in Part I, are particularly poignant today in the context of statistics pedagogy. Scheaffer (2010) identifies a key driving force of much of what has happened since the late 1970s in the following observation

> *Data exploration (in the true Tukey sense) is much more than the classical 'descriptive statistics', is essential to good statistical practice, and serves as an effective way to capture the interest of others (students, in particular) in statistical reasoning. Technology, essential for data exploration, can be used effectively to enhance the learning of statistical reasoning and the learning of statistical methodology, both at the exploration and inferential stages. (In other words, statistics education has advanced over the last thirty years in large measure because Tukey made data exploration acceptable and Technology made it possible.)*

In New Zealand in the 1970s Geoff Jowett embarked on major work throughout the country holding workshops for teachers to train them in statistics and its teaching. Wild (1994, 1997) and Wild and Pfankkuch (1999) have produced a series of papers that take a fundamental, some would say radical, look at the way statistics is taught and practised. In an important forthcoming paper Wild et al (2010) argue that there is a compelling case, based on research in statistics education, for first courses in statistical inference to be underpinned by a staged development path. Preferably over a number of years, students should begin working with informal inference, or precursor forms of statistical inference, much earlier than they now do. In our view these are probably the most important papers that have appeared in the last 16 years aimed at improving the teaching of statistics. In particular the ideas in Wild et al (2010) should enable teachers of statistics to fundamentally re-think how they communicate statistics to early learners of the subject.

However, in many countries a misconception still persists that just because people are knowledgeable in statistics, they can teach it effectively. For example, the greater importance that Australian funding bodies give to research and refereed publications in statistics, when compared with promoting pedagogic activities, has been a cause for concern in higher education. The Statistical Society of Australia Inc (SSAI) has grappled with these issues, but the outcomes have not always been satisfactory. At school level overly-rapid changes to the school curriculum, including, for example, a tendency for the use of graphics calculators taking preference over the use of computer technology and associated software, has held back the broader statistical educational opportunities for learners. Also, at least one state in Australia assesses through centrally set examinations, and some people feel that this is overly restrictive for dynamic development of syllabuses. More recently in Australia, however, there have been some positive developments. University level teachers are expressing a greater willingness to acknowledge the need to learn more about statistical education. The Australian Learning and Teaching Council was established and this led to awards of national fellowships in teaching, including one in statistics. The running of Australian versions of ICOTS (OZCOTS) conferences since 1998 has firmly put teaching statistics on the agenda for schools and universities. It is now run as a satellite for the annual Australian Statistics Conference.

In the UK the Royal Statistical Society has accredited two courses on statistics pedagogy. The first, accredited in 2004, leads to a *Certificate in Teaching Statistics in Higher Education*. This is a part-time distance learning course that takes about 18 months to complete and is concerned entirely with pedagogy (and not statistics knowledge enhancement). See www.rsscse.org.uk/activties/he-activities/tsihe for details. The second, accredited in 2009, is also a distance learning course, but with four contact days, and leads to a *Certificate in Teaching*

Statistics up to Pre-university Level. The course is aimed at school teachers who wish to improve their statistics pedagogy *and* knowledge. See www.rsscse.org.uk/activties/for-school/tsise for details.

Smith (2001) notes an apparent paradox in that in a world that produces ever more quantitative information there appears to be less and less appreciation of the power of statistical thinking. He suggests that the statistics profession should exploit public concerns about the risk aspect of public policy as a possible pedagogic route to raising statistical awareness. We are not aware that Smith's proposals have been taken up, but it is our view that better statistics pedagogy is a key way to help promote the improvement in statistical education for people of all ages. This is especially true for people in the workplace.

EMPLOYEES NEED TO DO STATISTICS

Statistical literacy is increasingly seen as an essential skill so that people can become responsible citizens and be better equipped to make sense of the vast amount of data available to us. It has been lamented by employer's organisations in the UK that new school leavers and university graduates do not possess key statistical skills. The consequences of this are that the responsibility for establishing statistical literacy in the workplace, generally through short and specifically-targeted training courses, usually rests with employers.

Government organisations sometimes publish a list of statistical competencies that they expect their employees to achieve. For example, in 2002 the UK Office for National Statistics (ONS) embarked on a statistical training needs analysis and produced a set of competencies, see Underwood (2007). However, the publication of such expected levels of statistical skills and knowledge are rare, and are only implicitly defined by national and international standards.

Greenfield (1979, 1993) emphasises the need to communicate statistics in a way that non-specialists can understand. These people often need the unique features of statistics that enable them to tease out information from data their subjects produce. From Greenfield's papers we learn that using high levels of technical language or unnecessary mathematics can cloud the pictures that statistics can paint for business and industry. We discussed this in part I of the paper.

Gal (2002) argues that for an adult to be able to act in a statistically literate manner a range of different knowledge bases and skills are needed. Marriott et al. (2009) give examples of these when a person carries out the procedures necessary to use statistics to solve problems. They stress that we cannot simply expect people to possess the cognitive skills necessary to solve problems without getting experience with the process of statistical problem solving. Hoyles and Noss (2010) report their study to discover the extent and form of techno-mathematical literacies possessed by people in the workplace and reveal that the need for statistics is paramount.

While much more needs to be done to ensure that a statistically literate workforce is available, there remains a good deal of effort needed to get employers to recognise that empowering their workforce with even basic statistical skills can only improve their businesses. This will not be done overnight.

IT MIGHT TAKE A LONG TIME…

It is one thing to write about what we have learned about statistical education in the last hundred years, it is quite another to put the lessons into practice across all sectors of formal education, let alone embedding the improvement of statistical literacy in the workplace. In many HE academic disciplines, in the UK at least, there has been an inexorable drift towards a situation in which statistics is no longer taught by statistically trained and qualified teachers, see, for example, Smith and Staetsky (2007). This presents a new challenge in Higher Education in that many teachers of statistics are not now qualified in the subject and do not have appropriate levels of pedagogic knowledge or skills. At school level it is rare for mathematics teachers to be qualified in statistics, let alone be aware of its pedagogy.

The statistical education community need to join forces to promote statistics recognising what we have highlighted in Parts I and II of this paper, namely that:

a. it is not mathematics;
b. real data should be used;

c. it should be taught using a problem solving approach;
d. it needs an improved pedagogy;
e. it is urgently needed in employment.

Recognising that there is a dramatic shortfall in the quantitative skills of social science graduates in the UK, the Economics and Social Science Research Council (ESRC) has embarked on an initiative to produce a course in quantitative methods that will benefit students of social sciences. This course is being designed taking into account (a) - (e) and is also likely to be useful to students outside the social sciences area. In a similar initiative, UK colleagues in the science, technology, engineering and mathematics (STEM) subjects have recognised that graduates in those subjects have little statistical awareness when they enter employment, even though they may have studied one or more courses in statistics at university level. They are proposing a course that will not only be useful to recent STEM graduates, but also to employees already in the workplace who need to improve their statistical literacy.

It is clear to us that high quality statistical education/training material is needed that covers a curriculum that focuses on content and that is delivered taking into account (a) – (e). Bringing together school teachers, university academics and stakeholders from business and industry will be crucial for the development of effective courses. At the University of Auckland in New Zealand researchers are using research-informed teaching practice to produce material for teachers of statistics in schools. In particular the new approach of Wild et al (2010) has great potential for helping improve early learning of statistics, not just in school, but beginning learners of the subject of any age. We expect this paper to be a goldmine of resources for the future.

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