

ALTC Senior Fellowship Report

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**The teaching and assessment of statistical
thinking within and across disciplines**

July 2009

<https://teaching.sci.qut.edu.au/data2teach/>

<http://sky.scitech.qut.edu.au/~macgilli/ozcots2008/>

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Overview

Statistics is increasingly important within and across disciplines, with the proliferation of data, the demand for evidence-based decision-making and the power of technology enabling quantitative tackling of more complex real problems which almost always require at least some modelling of uncertainty or variation.

Statistics education is therefore more important than ever. The statistics education reform movement of the past fifteen years emphasizes more concepts, more data and fewer calculations. Concepts of statistical citizenship, statistical literacy, statistical reasoning and statistical thinking are increasingly influencing developments and policy across all educational levels. Combinations of research in learning and teaching in statistics, considerations of the nature of statistical enquiry and how statisticians think, and general educational research are developing principles, strategies and resources in statistics teaching in higher education. Previous strategies that were teacher-centred, with theory followed by examples, are supplanted by student-centred, data- and context-driven, experiential learning and assessment, with emphasis on concepts and development of statistical thinking. However, despite much work and progress, learning and teaching in statistics continues to present significant and extensive challenges. The fellowship aimed to identify and tackle these challenges.

In the year before the commencement of the fellowship, the program was shaped by a range of influences and events. These included attending and presenting a paper in the International Association for Statistical Education (IASE) conference on Assessing Student Learning in Statistics; attending the 56th Session of the International Statistical Institute (ISI); participating in planning for the 57th Session of the ISI for which I am on the International Planning committee in charge of statistics education; being appointed scientific coordinator for the next International Conference on Teaching Statistics in 2010; and being elected to the position of President-elect of IASE for 2007-2009, with the term as President being 2009-2011.

The fellowship program was a journey that involved discovery, dissemination, analysis, synthesis and development, and linked the past with the future through an accelerated and rich program. The program included delving beyond the research and conference papers, and examining where statistical education is at and where it should develop. Dissemination of my work enabled feedback and collaboration to influence and inspire further developments. Information from observation, and analysing the commonalities and contrasts across learning and teaching contexts has also greatly contributed to findings and ongoing work. The fellowship program has already made significant contributions to building networks and understanding to bridge the many divisions in the worlds of statistics and statistics education, and it is intended to pursue this further during my presidency of the International Association for Statistical Education.

During my fellowship program, I visited sixteen universities and held discussions with many staff in six different countries; gave seventeen seminars and two public speeches; conducted five workshops and one forum; attended four conferences, giving a plenary at one, an invited paper at another, and contributed papers at the other two; and sat in on thirteen different courses. This included working with twenty-one collaborators who are listed in section 4 of the report. These activities of discovery, dissemination, collaboration, observation and interaction have provided an extensive and rich source to inform reflection, analysis and synthesis. This synthesis of findings has fed, and will continue to feed, into my teaching, my support of staff and students, my writings and development of resources.

A highlight of the fellowship program was the 6th Australian Conference on Teaching Statistics (OZCOTS) on 3rd & 4th July, 2008, in Melbourne, held for the first time as a satellite conference to the Australian Statistical Conference.



A forum entitled “Building Networks in Statistical Education” was held for statisticians and statistical educators from Australia and New Zealand at QUT on 9th & 10th February, 2009.

I revised my teaching materials and resources for introductory statistical data analysis and introductory modelling with probability and distributions, incorporating innovative approaches designed to facilitate learning and assessment of statistical thinking for today’s student cohorts in a modern information society.

Preparation of datasets and materials from student free-choice data investigation projects was undertaken for the development of a website of authentic and rich datasets with notes and teaching comments. Extending and maintaining this website will be an ongoing commitment. A second website on teaching tips has been designed, and its development is ongoing.

A DVD, four invited papers and two invited book chapters have been finalised. Another ten papers are in preparation, or have been scoped, each with a different collaborator. I have been asked to provide advice or input on a variety of writings, proposals or reports.

After providing a brief overview of some background on the components of the challenges in teaching and assessment in statistics, the report briefly describes influences on the fellowship program in the year between the award and the commencement of the fellowship. A list of the main international and national collaborators is provided in Section 4. Section 5 gives details of activities and their outcomes, influences and results. The report concludes with descriptions of the outcomes of the fellowship (Section 6), including ongoing activities, research and development.

Overall, from the synthesis of activities, research and analysis, my fellowship has helped to build the foundations for the way forward for me and hopefully for my colleagues and collaborators – in curriculum, pedagogical and resource development that is harmonious and meaningful across educational levels and disciplines, in the teaching and assessment of statistical thinking.



1. Introduction

General challenges in teaching statistics

Statistical thinking in the broad sense of making sense of information in which variation is present, pervades disciplines, workplaces and research. Whether information is qualitative, quantitative or a mixture, and no matter how it is obtained, the presence of variation requires at least some element of understanding the science and art of handling variation. Like communication skills, no discipline is immune from the need for statistical thinking, even if the forms, contexts and applications may depend, to a greater or lesser extent, on the discipline.

The increasingly critical roles of data and evidence-based decisions, and the rapid increase of computer power also mean that there are constantly new statistical methodologies, applications, software and research techniques being developed, driven by the needs across an increasing range of disciplines, work contexts and complex real problems. Because of the pervasiveness and importance of statistical thinking within and across disciplines, it is not surprising that the teaching and assessment challenges to academic staff in statistical thinking are both extensive and significant, and often greatly under-estimated.

A former president of the American Statistical Association, David Moore (1990) wrote, “Statistics has some claim to being a fundamental method of enquiry, a general way of thinking that is more important than any of the specific techniques that make up the discipline”. The past twenty years have seen significant reform, innovations and progress in the learning and teaching of statistics across all educational levels and into the workplace. The International Association for Statistical Education was formed in 1991. Alongside these developments, there has been a considerable increase in the research, literature and scholarship in the area of the teaching and learning of statistics, to the point where statistics education is now a research field in its own right, supporting journals such as the *Journal of Statistical Education* (JSE), the *Statistical Education Research Journal* (SERJ) and *Teaching Statistics* as well as annual international conferences, roundtables and satellite meetings, and numerous national and local meetings throughout the world. In addition, the learning and teaching of statistics features in the research, literature, conferences and discussions in other disciplines, such as engineering, social sciences, all business areas, health and agriculture.

Despite the quantity, quality and extent of the work in statistical education around the world, learning and teaching in statistics continues to present formidable challenges. Reasons for this include:

- Statistics and the need for statistics are everywhere, and are needed at many levels from citizenship to highly specialised
- Statistics involves a way of thinking that is both mathematical and non-mathematical
- Statistics is all about uncertainty and variation. Data are inherently messy and statistical exploration and analysis of data need to be experienced to understand statistics
- Statistics is highly conceptual, and context dependent but is vulnerable to context “intuitions”
- Statistical interpretations depend on assumptions, and there is a human tendency to try to impose rules on uncertainty that do not depend on understanding and interpretation
- In all disciplines there is need for ownership of learning, but this is essential in fundamental and foundational disciplines such as statistics and mathematics. Learning experiences for ownership of learning need to be authentic, familiar, and link with everyday experiences

Learning and teaching, and their associated scholarship and research, are strongly



associated with their contexts, whether they be educational levels, cohort characteristics, national, historical or socio-economic. This is particularly so for the world of statistics, and yet one of the components of the power of statistics is its transferability and universality.

2. Background: components of the challenges

2.1 The nature of statistical thinking

Over the last decade there has been significant debate and production of a body of literature on the concepts of statistical understanding, literacy, reasoning and thinking. Just some examples are Snell (1999), Wild and Pfannkuch (1999), delMas (2002), Rumsey (2002), Garfield (2002). Clarification and modelling of the concepts and workings of statistical understanding lead to an increased focus on what should be taught and assessed. Apart from Wild and Pfannkuch (1999), much of the recent debate has been oriented to introductory courses or units. There is a need not only to facilitate access for all academic staff to the principal findings and their implications for practising teachers, but also to further develop the research and thoughts of Wild and Pfannkuch (1999) and Bartholomew (RSS presidential address, 1995) who discusses the types of statistical development to achieve a statistically-educated society with the necessary range of statistical numeracy.

2.2 Introductory statistical data analysis

Much of the work of the past decade in statistics education has been motivated by, and oriented to, introductory tertiary data analysis courses, particularly for non-quantitatively-inclined students (Garfield et al, 2002) and with great emphasis on data (Cobb, 1999). Calls for statistical educators to consider carefully and in depth the objectives, goals, contexts and content of introductory tertiary statistics courses (Hogg, 1991, Vere-Jones, 1995, Moore, 1997) has led to what is sometimes called the “statistics education reform movement”. These calls are echoed in the general higher education literature on objectives and on assessment (Angelo, 1999).

The work of statistical educators has been particularly driven by the challenges of introductory courses for students in other disciplines, including engineering, health, social sciences, business, law, environmental sciences, and it is these courses in particular that have motivated the focus on data-driven, realistic approaches to building statistical literacy and data analysis curriculum (Pfannkuch et al 2003, Schield 2005). Large projects on developing resources, particularly in the US, have also focussed mainly on the introductory “service” course.

2.3 Probabilistic statistical thinking

The “statistics education reform movement” has tended to focus on statistical data analysis and the “empirical enquiry” of statistical work (Wild and Pfannkuch, 1999). Statistical modelling is the modelling of any situation that involves variation and uncertainty. Integral to any such situation are context, data, probability, distributions; it is the nature of the particular context and the problem under consideration that determines the composition of the mix. To advocate that probability is merely a branch of mathematics is to risk trivialising statistics and statistical thinking. The implications of this for stochastic modelling are at least twofold: it must also be driven and built around authentic contexts, and it must link with data. Perhaps because fewer students are involved in such courses and because of society's imperative needs for statistical literacy, or perhaps because of the challenges involved, tertiary levels beyond the introductory and in statistical modelling in its broad sense have featured less in statistical education literature. Much work is needed on introductory probability modelling and statistical modelling in its broad sense of including stochastic modelling and discovering and discussing innovations in these areas, such as those described in MacGillivray (2006, 2007).



2.4 Building on foundational learning

As Wild (2006) emphasizes, building successfully on foundational learning in statistical thinking is of critical importance both in the training of statisticians and in all disciplines that require statistical thinking. Not only is any literature on this aspect of statistics education scattered, but the task of genuine discovery and integration of prior (and future) student learning into one's teaching is also one of the most time-consuming and difficult tasks for academic staff to achieve. It is also a quality that consistently features as being desired and prized by students in their feedback on tertiary courses.

2.5 Students' self-efficacy and attitudes to statistics

Gal et al (1997) point to the influence of attitudes and beliefs about statistics on student learning. Academic staff teaching statistics within introductory courses or units are well aware that, currently, very few students arrive with positive attitudes to statistics despite the general community knowledge that statistical thinking is important to society. The quantitatively-inclined students tend to think that statistics is "boring and tedious with none of the mathematics ..." they love. The non-quantitatively-inclined students attribute their dislike of statistics to their feelings about numeracy in general. There is almost a direct correspondence between students who arrive with positive attitudes to statistics and their school teachers who have studied and liked statistics themselves, either in their undergraduate degree or in subsequent professional development.

2.6 Understanding how students learn statistical thinking

Understanding how students come, and continue, to learn statistical thinking is significant in helping develop teaching and assessment strategies. An example of some recent research in Australian contexts is that of Petocz and Reid (2001) who have used in-depth interviews and phenomenography to model students' different concepts of learning in statistics. They described students' conceptions in terms of six hierarchical levels: doing, collecting, applying, linking, expanding and changing. In the lowest level, doing, students saw learning as simply performing the required statistical activities to pass the assessment. At the highest level, changing, learning was seen as being about using statistical concepts in order to change their views.

2.7 The roles of numeracy and mathematics in learning and teaching statistics

The British Cockcroft Report of 1982 first popularised the term 'numeracy' giving an informal definition of:

'an "at-home-ness" with numbers and an ability to make use of the mathematical skills which enable an individual to cope with the mathematical demands of his everyday life'.

While educational literature differentiates between the terms 'numeracy', 'quantitative literacy' and 'mathematical skill', in many situations such differences are irrelevant and Cockcroft's definition brings to our attention some important matters. In particular it emphasises that both familiarity and skills are needed to achieve applicability as well as highlighting the fact that a desired level of competence depends on the specific demands of an individual's circumstances.

Much of the literature described above on the learning and teaching of introductory statistics and data analysis has been motivated by the challenges of teaching math-phobic or at least non-quantitatively-inclined students in other disciplines. Little attention has been given to research on teaching quantitatively-inclined students in other disciplines.



The roles of numeracy in developing statistical thinking cannot be ignored or denied (Wilson and MacGillivray 2006) but must also not be emphasized at the expense of the statistical thinking.

2.8 Datasets and data investigations

There is general and strong agreement about the importance of experiential learning with data and data investigations, but there is a range of views about the nature of datasets and data investigations for learning. Academic staff in all areas and levels are continually searching for datasets suitable for teaching and assessing statistics. Resources of datasets have been developed, but the search for suitable datasets is one of the most common and vociferous from teachers of statistics. Desirable qualities of datasets for teaching and assessment are variety, appropriate context, suitable for student learning, and illustrative of the learning objectives. Since 1994, my strategies of free-choice data investigation group projects in large classes have significantly shaped my teaching, resources and assessment. Selections of these datasets have proved immensely valuable in teaching, and there have been requests from tertiary teachers around the world for access to these datasets with sufficient information to permit ready selection for the teacher's purpose. Although there is general agreement about the core role of the data investigation cycle of Plan, Collect, Process and Discuss, there is a need for better understanding of the roles of different types of data situations and different views on incorporation of data investigations in statistical learning and assessment.

2.9 Assessment of statistical thinking

Changes in content have led to changes in assessment practices with the call for teachers to assess what they value (Chance 2002), although Garfield et al (2002), in a survey of statistics educators in the US, discovered that of all areas of statistics education, assessment practices had undergone the least reform. Assessment practices can have an explicit educational impact. MacGillivray (1998) explains how the use of own-choice group projects can synthesize knowledge for meaningful use.

Recent emphasis in the tertiary sector on criteria-based assessment has highlighted the difficulties for discipline-based tertiary teachers in absorbing, analysing and reconciling the various nearly disjoint bodies of literature on the topic. This is particularly so in areas such as statistics, and at the introductory level with large and highly diverse cohorts in backgrounds and capabilities. The work of researchers such as Sadler (1998), O'Donovan, Price and Rust (2004), together with work in the school context with teachers and educational authorities, and the research of statistical educators, need to be brought together, discussed and extended to develop strategies for criteria and standards referencing in assessment of statistics at the tertiary level (MacGillivray, 2005).

2.10 Research methods and postgraduate courses or research

The increase in the number of research methods courses and units across disciplines is yet another indicator of the importance of statistical thinking. Although such courses are often claimed to be qualitative or exclusive to a discipline, they all, as discussed above, include at least some aspects of statistical thinking and understanding of foundational statistical concepts and methods. As with numeracy, balance and understanding of the roles of statistics in such courses are needed.

Other areas of postgraduate study in which assistance with the learning and teaching of statistical thinking is needed include, specific, statistical methods courses such as are found in MBAs, and in the foundational understanding of statistics needed by postgraduate research students across disciplines in their planning, collection and analysis of data. Statisticians and teachers of statistics need to collaborate in research and practice to develop principles and strategies for programs and staff across disciplines and within research students' support services.



2.11 Research and education at the school level

Since 1990, Chance and Data have been significant strands in all Australian school syllabi with similar developments taking place worldwide. It is widely recognised that significant assistance is needed to help teachers at all school levels with strategies, resources and understanding to teach statistical thinking. This is a major component of the work of the Royal Statistical Society's Centre for Statistical Education which is based in the UK but whose resources are being used in Australia, South Africa, Canada and New Zealand. The combination of school and college teaching of statistics in the USA has been a major driver of the development of projects, programs and resources in that country with associated world-wide influences.

2.12 The roles of technology

The extraordinary impact of technology on the learning and teaching of statistics has been one of the driving forces in the statistical education "reform movement" of the past decade. Ben-Zvi (2000) proposes a *reorganization metaphor*, arguing that appropriate use of technology can bring about structural change by allowing the student to focus on higher order tasks. Cobb (1999) states that:

"The increasing use of computers, not just within the discipline but in society in general has placed an increasing premium on qualitative reasoning in general and on statistical reasoning in particular."

There has been rapid growth of literature and resources in this area, but the challenges of implementing and integrating these into practical situations with the goal of developing statistical thinking are not trivial.

2.13 The supply and training of statisticians

The recent review of Statistics in Australian Universities sponsored by the Statistical Society of Australia (SSAI) (enquiries to <http://www.statsoc.org.au/contact-us.htm>) was mostly motivated by employers' concerns over the lack of supply of statisticians – a concern shared by other countries. The Review found that much of this is caused by the increasing demand for statistically trained graduates in finance, government and industry. Wild (2006) argues that one of the key methods to tackle this problem is the focus on best practice in teaching "service" courses and building on this foundation.

2.14 Learning to teach statistics

Because of the pervasiveness and importance of statistical education across all levels of education and most disciplines, there are many challenges for the world of statistical education, for the statistical profession and for higher education in developing and implementing models for learning to teach statistics. One example of a recently developed approach is the Royal Statistical Society's (RSS) Certificate in Teaching Statistics in Higher Education, and their programs for continuing professional development. (<http://www.rsscse.org.uk/activities/he-activities/tsihe>).



3. Influences from 2007

During 2007, before commencing the fellowship year in November, a considerable number of informative influences helped to refine and shape details of my fellowship program. These included: formal and informal meetings with other Carrick/ALTC fellows; preliminary discussions with my international collaborators; attending and presenting a paper in the International Association for Statistical Education (IASE) conference on Assessing Student Learning in Statistics; attending the 56th Session of the International Statistical Institute (ISI); participating in planning for the 57th Session of the ISI for which I am on the International Planning committee in charge of statistics education; and being elected to the position of President-elect of IASE for 2007-2009, with term as President being 2009-2011. The IASE is truly international with a record on executive members from all over the world, and working with the IASE has significantly boosted my knowledge and understanding of statistics education around the world.

Valuable background information also arose throughout 2007 via the research, contact and interaction with universities and staff across Australia and the UK through my ALTC-funded Leadership project *Quantitative diversity: disciplinary and cross-disciplinary mathematics and statistics support in Australian universities*.

The above influenced planning details of my fellowship program through demonstrating that I needed to place greater emphasis earlier in my program on more in-depth discovery of learning and teaching situations in English-speaking countries other than Australia and the UK, of which my knowledge was already extensive, and on greater dissemination of my teaching pedagogies and materials in these countries in order to benchmark my work. In addition, discussions and conference papers in 2007 encouraged me to write materials for a proposed innovation to both trial and include in seminars and discussions early in 2008. This is described below in (5.5).

The planning of timelines of activities also had to adapt to practicalities and the need to coalesce plans across people and places to meet objectives within restrictions of others' frameworks. For example, I wanted to ensure that discovery in other universities occurred during their teaching times.

The fellowship program and its outcomes aim to be relevant to the whole world of statistics education, but a comment is needed on focussing detail of the fellowship program on English-speaking countries. This is of course a natural focus for the sharing and benchmarking of materials and resources, but it is also because statistics education around the world has been shaped by countries' histories and socio-economic developments as described by Vere-Jones (1998). The UK, Australia, New Zealand, Canada, USA and South Africa are linked in the histories and development of their educational systems, although there are differences amongst them that are highly significant in the type of detailed knowledge necessary in my fellowship program. Scandinavia, Spain, Portugal and Italy have more in common with each other and indeed with English-speaking countries, than do France, Germany, Eastern Europe, Russia and China. The Middle East tends to have more influences from this latter group than from others. India and Pakistan have some unique characteristics shaped by the combination of English-speaking influences, their socio-economic history and some remarkable individuals. Other SE Asia countries and South American countries are influenced by the combination of historical links and current student and research connections. Japan has some influences arising from earlier manufacturing developments.



4. Key collaborators

Collaboration with staff and interaction with staff and students in many universities were extensive throughout my fellowship, during my visits to other universities and other countries, during conferences and the events (conference, workshops and forums) that were specifically part of the fellowship program. Wherever I went, staff and postgraduate students were eager to discuss my seminars, and learning and teaching in statistics in general. Listed below are staff with whom I interacted for considerable time and/or over an extended period, and a brief comment on their particular interests in learning and teaching in statistics.

Professor Adrian Bowman, Glasgow University

Use of technology; holistic problem-solving; graphics

Professor Chris Wild, Auckland University

Statistical thinking; team teaching; technology and virtual environments

Dr Larry Weldon, Simon Fraser University

Problem immersion; non-parametric emphasis

Professor Michael Martin, ANU

Multiple ALTC award winner; analogies in teaching statistics; developing seamless curricula

Dr Rob Gould, UCLA

Use of technology in teaching statistics; Tinkerplots; professional development for college and school teachers

Associate Professor Delia North, KwaZulu-Natal University

South African leader in statistics in schools and teacher professional development; probabilistic thinking

Dr Christine Reading, UNE

Mathematics, statistics and IT educationalist; distance learning; assessment

Associate Professor Peter Petocz, Macquarie

Pedagogical aspects of statistics and mathematics; graduate 'dispositions'

Dr Brian Phillips, Swinburne University

Australian Conference on Teaching Statistics

Dr Allan Rossman, Cal Poly

President IASE, 2007-2009; active learning

Mr Michael Forster, Auckland University

Statistical curricula, pedagogies and practicalities for very large classes (1300-4500); free-choice data investigation group projects

Mr John Harraway, Otago University

Chair, International Conference in Teaching Statistics, 2010; resources for teachers; introductory statistics

Dr Richard Gadsden, Loughborough University

Learning support in statistics across disciplines for undergraduates and postgraduates

Professor Tony Croft, CETL, Loughborough University

Creating learning environments in mathematics and statistic; learning support in mathematics and statistics;

Dr Neville Davies, Royal Statistical Society Centre for Statistical Education

Resources for statistics education; data investigation cycle; web-based resources

Professor John McColl, Glasgow University

Web-based resources for tertiary statistics learning and teaching; statistics in other disciplines; foundations in statistics



Dr Helen Johnson, QUT

Teaching introductory and advanced data analysis and statistical techniques; introductory modelling with probability and distributions

Dr Helen Thompson, QUT

Statistics for medical, pharmacy and bioscience; teaching experimental design

Dr Therese Wilson, QUT

Statistical thinking at the school/tertiary interface; statistical and probabilistic thinking and their elicitation

Dr Harry Bartlett, QUT

Teaching reliability, engineering statistics; school/tertiary interface in statistics and mathematics

Dr Ewan Crawford, Glasgow University

IT specialist in designing web-based resources for statistics

5. Fellowship activities and their outcomes, influences or results

5.1 Brief summary of activities

The fellowship program was a journey that involved discovery, dissemination, analysis, synthesis and development, and linked the past with the future through an accelerated and rich program. The program included delving beyond the research and conference papers, and examining where statistical education is at and where it should develop. Dissemination of my work enabled feedback and collaboration to influence and inspire further developments. Information from observation, and analysing the commonalities and contrasts across learning and teaching contexts has also greatly contributed to findings and ongoing work. The fellowship program has already made significant contributions to building networks and understanding to bridge the many divisions in the worlds of statistics and statistics education, and it is intended to pursue this further during my presidency of the International Association for Statistical Education.

As outlined in the Overview, I visited sixteen universities and held discussions with many staff in six different countries; gave seventeen seminars and two public speeches; conducted five workshops and one forum; attended four conferences, giving a plenary at one, an invited paper at another, and contributed papers at the other two; and sat in on thirteen different courses. This included working with twenty-one collaborators who are listed in the report in Section 4.

Holding the 6th Australian Conference on Teaching Statistics (OZCOTS) on 3rd & 4th July, 2008, in Melbourne, as a satellite conference to the Australian Statistical Conference (ASC) was one of the main events of the fellowship program. This overlap with the ASC facilitated participation by statisticians in a statistical education conference, and bringing together statistics academics, researchers, practitioners and educators. The organisation of the committee, venue, program, publicity, invited speakers, contributed papers, refereeing and proceedings were all part of the fellowship program. It was an outstanding success, with standing room only in the sessions that overlapped with the main ASC program. The organisers of the next ASC immediately decided to make the same arrangement of an OZCOTS overlapping with the ASC.

The forum for statisticians and statistical educators from Australia and New Zealand, entitled “Building Networks in Statistical Education” also emphasized bringing together practitioners, researchers and educators. The forum commenced with reports from the fellowship and from national and international organisations, but was then devoted entirely to facilitated



discussion sessions on a range of selected topics, with key points and comments recorded or reported from each session.

Throughout the fellowship program, there was considerable interest in my teaching materials and resources for introductory statistical data analysis and introductory modelling with probability and distributions, incorporating innovative approaches designed to facilitate learning and assessment of statistical thinking for today's student cohorts in a modern information society. QUT colleagues who chose to use my materials provided feedback and qualitative and quantitative evidence of effects. Universities I visited requested copies of the materials, and at least two are already incorporating them in their approaches.

The pedagogies, practicalities, assessment and learning effects of the student free-choice data investigation projects also attracted considerable attention wherever I visited. Examples of projects and their datasets were included in seminars and discussions throughout the program. Feedback from these assisted in the preparation of datasets and materials for the development of a website of authentic and rich datasets with notes and teaching comments, helping to ensure the usefulness of this resource. With the assistance of Dr Crawford, this website was designed and established. Feedback was obtained from Glasgow University collaborators during the design process. Extending and maintaining this website continues and will be an ongoing commitment. A second website on teaching tips has been designed, and its development is ongoing.

5.2 Detail of activities and outcomes/influences: South Africa

The activities of the senior fellowship commenced in November 2007, with my official visit to South Africa for the South African Statistical Association (SASA) and Statistics South Africa (StatSA). Dr Delia North, Head of the School of Statistics and Actuarial Science, University of KwaZulu-Natal, and a member of my international collaborative team, had proposed me as a plenary speaker for the 50th Conference of the South African Statistical Association, and to her great delight this was accepted. South Africa has a long tradition of quality research in statistics, so the choice of a plenary speaker in statistics learning and teaching in higher education is significant. The award of an ALTC Senior Fellowship contributed to this choice, as had also my election during 2007 to the position of President-elect of the International Association for Statistics Education. The visit to South Africa was a scheduled component of the fellowship program, but the extension and financial support of the visit by SASA and StatSA had two major advantages. They generated more activities in the fellowship program, and enabled the fellowship program to commence with major impact at the beginning of November, providing the funds necessary to arrange such a visit months before the actual travel.

My plenary topic of *Real data, real projects, real students* discussed the pedagogy, practicalities and impact on student learning and on teaching, of the free-choice group projects in data investigations that I have established and developed at QUT since 1994. The presentation aimed to connect real statisticians with the rich but workable possibilities at the coalface of teaching introductory statistical thinking and analysis in data investigations across a range of disciplines. Discussion and feedback after my plenary was indicative of the interest in the South African statistical community in possible ways forward in teaching and learning statistics in both mainstream and service courses.

As official visitor and a plenary speaker, I was also asked to give a day-long workshop before the conference, and to visit a number of universities after the conference. My workshop, *Coherent and Purposeful Development of Statistical Thinking across School Levels*, was given to a diverse group of approximately 100, mostly school teachers, but also tertiary staff interested in statistical aspects of school curricula. The workshop content has evolved from more than a decade of helping teachers and curriculum developers in Queensland, particularly across middle and senior school (student ages 10-17). The workshop emphasized data investigations, explorations, and foundations for statistical development, covering: *good, bad and wrong graphs; connecting with chance; planning investigations;*



types of data; types of graphs; collecting and handling data; and commenting on graphs and variation. During the workshop, participants carried out the initial brainstorming for one data investigation, and the planning and a pilot for another. The enthusiasm and engagement were excellent, and the questions, reactions and feedback reflected the commonalities across all countries and backgrounds – teaching data and chance at middle and senior school levels is challenging and needful of support and help from the statistical community, but can be a source of satisfaction and progress for all concerned. On the second day of workshops, I observed the session on probability games and was impressed by the subtleties in the games which provided excellent non-trivial connections with data and sampling variability. On both days, teachers were eager to learn about statistics and about schooling in Australia.

The South African universities “bid” for visits from the plenary speakers, and Dr North chose four from amongst the eight universities that “bid” for me. My first university visit was to the Department of Statistics and Actuarial Science on the Westville campus of the University of KwaZulu-Natal, with staff from the Pietermaritzburg campus joining us for my seminar and the following wide-ranging discussion. My presentation on *Developing probabilistic statistical thinking* gave rise to many questions and comments from staff, sometimes sceptical but always demonstrating the strength of commitment to developments in teaching and learning to best serve the long term interests of students and society.

At the University of Pretoria, I gave a seminar on the *Roles of assessment in learning in statistics and mathematics*, followed by extensive questions and comments from the audience. I also visited the Mamelodi campus (a black campus of the University of Pretoria) where discussion focussed on challenges at that campus in assessment for learning in statistics. My visit to the Department of Statistics of the University of Witwatersrand, focussed on comparing teaching, curricula and student experiences with staff. They also chose the seminar *Roles of assessment in learning in statistics and mathematics*, but the interest after the seminar from dedicated young staff members developed into questions about the system of apprenticing, training and accrediting tutors I have developed at QUT in conjunction with the QUT Maths Access Centre and colleagues in the School of Mathematical Sciences.

The University of Capetown also chose the seminar on the roles of assessment and again the audience’s questions and comments were searching and indicative of the commitment of staff to quality learning midst the enormous challenges in South Africa of increasingly diverse cohorts with changing backgrounds, motivations and interests.

The time in South Africa also included meetings on a range of matters for the 57th Session of the International Statistical Institute (ISI) which is being held in South Africa for the first time, and for which I am in charge of all the statistics education sessions and activities.

5.3 National Symposium on Mathematics Education for 21st Century Engineering Students

In December, 2007, I participated in the National Symposium on Mathematics Education for 21st Century Engineering Students, organised by the Australian Mathematical Sciences Institute (AMSI) and sponsored by the then Carrick Institute for Learning and Teaching in Higher Education, RMIT University and elsewhere by access grid technology. My paper, *The multi-layered challenges of teaching statistics in engineering courses* was well-received. It was the only paper addressing the very important matter of the statistical needs in modern engineering education. Despite the importance and significance of statistical knowhow and thinking in modern engineering, this area is frequently neglected in discussions of engineering education.



5.4 Detail of activities and outcomes/influences: ANU

During January, 2008, I visited the Australian National University (ANU), primarily to hold intensive discussions with Professor Michael Martin, one of my collaborative team and a 2007 winner of a Carrick Award for Teaching Excellence in Law, Economics, Business and Related Studies. During my visit, I also gave a public lecture at ANU on assessment and learning in quantitative disciplines and discussed the challenges of teaching introductory statistics with staff who lecture students in economics, finance and other business courses.

Some of my discussions with Professor Martin centred on the roles of the free-choice group projects strategies I have developed over the past decade in a number of teaching contexts. My initial purpose in these discussions was from the point of view of developing resources based on the experiences and material from some 2000-3000 projects, and for both students and staff for future projects. However, Professor Martin was able to show me that the pedagogy and learning in the way I have developed the projects are different from the common view of projects, and that I should describe and write about them as statistical discovery tours. This is also consistent with my work in introductory probability and distributional modelling in creating a problem-solving environment as described by Gal et al (1997) as:

“an emotionally and cognitively supportive atmosphere where students feel safe to explore, comfortable with temporary confusion, belief in their ability and motivation to navigate stages.”

My other discussions with Professor Martin on the content and structure of introductory data analysis courses were as illuminating as they were surprising, as we have interacted with each other for a long time and knew we were in agreement on the core principles of teaching and assessment of statistical thinking. We were surprised to find that those principles had led us to develop introductory units that might appear different to observers, but the differences are owing to their objectives rather than the underlying principles. This enabled us to more clearly identify and articulate core principles and practices in teaching and assessment of statistical thinking which, if followed, should avoid or remove many of the problems that still abound in introductory statistics courses despite almost twenty years of so-called “statistics education reform”. We therefore scoped a joint paper outlining our arguments with illustrative case studies. This paper has been accepted for the IASE 2009 conference on “Next Steps in Statistics Education”.

5.5 Innovations in curricula/materials for introductory statistical data analysis

During December, 2007, and January, 2008, I revised my curricula and materials for introductory statistical data analysis to incorporate an innovative approach designed to facilitate the data investigation approach making optimum use of technology. The possibility of this change had been discussed with local colleagues during 2007 and with some international colleagues during the 56th Session of the International Statistical Institute in Lisbon in August, 2007. The revisions aim to provide a more consistent and coherent approach to introductory data analysis courses whose objectives are to develop foundation skills in conducting statistical data investigations. On receiving local and international support and encouragement for initiating and trialling these proposals, I decided to rewrite my materials to be available for colleagues to use if they wished. Two of my QUT colleagues chose to use these materials in their courses and provided feedback and qualitative and quantitative evidence of the approach. These courses were for first-year science, mathematics and mathematics education majors, and for medical sciences, biosciences and pharmacy students. The qualitative feedback was excellent, with lecturers and tutors reporting that the new approach facilitated comfort and confidence in statistical thinking earlier than in previous approaches. Quantitative data in which conditions were matched with previous approaches, were analysed for the first course, and provided evidence of



improvement in student performance in most components of the course, particularly in statistical data investigations.

This approach was discussed during all visits to universities, and the materials provided. All universities visited during the fellowship expressed interest in the approach, and wished to be kept informed of the results of the trial. Following her visit to QUT in July, 2008, Associate Professor Delia North has introduced this approach in her university.

This approach is built around developing knowledge and skills for early learning in data investigations, and is inextricably linked with my strategies in free-choice data investigation projects, which promote student learning through discovery and ownership. The principles of these strategies have received acclaim at conferences, in papers and at universities visited throughout my fellowship program. Many of the questions asked by staff during my program concerned management and assessment as well as students' choices of topics to be investigated and effects on their learning.

5.6 Detail of activities and outcomes/influences: Vancouver, California

In April I visited Simon Fraser University (SFU) and the University of British Columbia (UBC) in Vancouver, Canada, and the University of California Los Angeles (UCLA) and California Polytechnic (Cal Poly) in USA. I gave seminars, attended classes and discussed widely across the spectrum of statistics education issues.

My visit to Vancouver and Simon Fraser University was primarily intended for collaboration with Dr Larry Weldon of my international collaborative team. Larry and I extensively debated the advantages and disadvantages of an array of strategies for learning statistical thinking, ranging across varieties and extents of partial problem immersion and experiences within, and/or parallel to, carefully structured frameworks of development of skills and knowledge. These debates were constructively informed by my prior discussions with Professor Martin at ANU, and also demonstrated the need for more extensive descriptions and understanding of teaching and learning contexts than are currently given in the literature and during conference presentations.

My seminar at SFU, titled *Learning statistical thinking in large classes through statistical discovery journeys* attracted a large audience and triggered lively discussion and many questions. Other topics on which staff and postgraduate students questioned me extensively included the Young Statisticians' Section of SSAI, Australia's Science Meets Parliament, statistics in school curricula, and advice for academics wishing to include major focus on teaching and professional work in their career paths. SFU has a tradition of a post-seminar meeting of the speaker with all the postgraduate students, and, as at the University of Witwatersrand, the SFU postgraduate students were particularly interested in my model of systematic mentored experience, training and accreditation of tutors in mathematics and statistics.

The invitation to give a seminar at UBC arose from my public seminar at ANU which was attended by a UBC staff member visiting ANU who recommended that UBC invite me to give that seminar during my stay in Vancouver. The seminar, on *Roles of assessment in learning in statistics and mathematics*, was within the seminar program of the Carl Wieman Science Education Initiative (CWSEI), a multi-million dollar funded centre at UBC, and was timed to enable Professor Wieman, a Nobel Prize winner in Physics, to attend as he specifically requested this. A wonderful side-benefit of this was spending two days in intensive and extensive discussion with a UBC staff member who was seeking advice on a number of challenges in teaching and assessment in both data analysis and probability modelling in and across disciplines. This interaction included attending a large class in statistics for biological science students using clickers for both participation and assessment, but not for feedback as is often advocated in Australia. This was very informative not only in helping analyse the lecturer's problems but also in seeing the use of fairly sophisticated clickers in a way that focuses on and assists student learning. In many North American universities,



students are asked to buy their clickers as a university will decide to use them across many courses.

At UCLA, another of my international collaborative team, Dr Robert Gould, is Director of the Centre for Teaching Statistics and Vice-Chair of Undergraduate Studies for the Department of Statistics. UCLA also chose to hear me speak on assessment in my seminar, but discussions with staff focussed on the data investigation projects, introductory probability, the training and mentoring of tutors, professional development for teachers, and the many differences between higher education teaching in the USA and in Australia, UK and NZ. Three key disadvantages in the USA systems for me are: the tyranny of the textbook in the USA (and to a lesser extent in Canada); the lack of consistency in assessment; and the unhealthy by-products of obsession with dividing subjects/courses with large enrolments arbitrarily into a number of lecture groups.

At UCLA I attended classes in four different subjects: introductory statistics for biological science/pre-med students; a general education subject in introductory statistics; a second level statistics subject; and a final year statistical consulting subject. As at UBC, and again at Cal Poly (see below), attending classes as well as interacting with staff outside classes, was invaluable in all aspects of discovery: the nature, background and attitudes of student cohorts; the good and poor aspects of different pedagogies and teaching styles; and the detail of the teaching contexts that is essential information for understanding and evaluating courses and teaching methods.

Cal Poly is regarded by many, particularly in the USA, as providing international leadership in teaching and assessing statistics within and across disciplines. The 2007-2009 President of the International Association for Statistics Education (IASE) was also at Cal Poly. Cal Poly chose to hear my seminar on *Learning statistical thinking in large classes through statistical discovery journeys* which provoked much lively discussion. I attended two classes at Cal Poly: one in a regression data analysis subject with many similarities in objectives, content and pedagogy to mine; and a final year statistical consulting subject that was the best example of that genre of subject that I've ever come across. Despite a number of university-cultural differences between us, I found much that was similar at Cal Poly to my core principles and pedagogies in teaching statistics.

5.7 Detail of activities and outcomes/influences: New Zealand – Auckland and Otago

In May I visited Auckland University and in May and October, I visited Otago University. The Statistics Department at Auckland University is the largest in the southern hemisphere and one of the largest in the world. Their first year course in introductory statistical data analysis has 4500 enrolments, with their second year course having approximately 1300 enrolments.

Auckland University asked me to give three seminars – on teaching data analysis through data investigation projects, on developing introductory modelling and problem-solving with probability and distributions, and on assessment. These were followed by two one-day workshops, one on teaching data analysis and one on teaching probability and distributions. I also sat in on classes in the first year and the second year courses, and participated in tutoring their first year course in introductory probability modelling. The two workshops were mutual learning experiences.

In data analysis, Auckland staff wished to find out as much as possible about my approach and curricula which enable students from a variety of disciplines to more quickly acquire knowledge and skills for data investigations. They also interrogated me extensively about the free-choice data investigation projects which Professor Wild, who is regarded as one of the world leaders in statistics education, has subsequently described as “one of the best things to come out of Australia”. As a result of this interaction, Mike Forster of Auckland University has visited QUT twice to discover as much as possible about the project strategies through reading students' project reports and participating in student discussions and planning. We



have developed additional resources, and Auckland University is now in the process of introducing the strategies in some of their service teaching with a view to building a teaching culture that will enable them to use these strategies more widely.

Mike Forster and I have been invited to deliver a paper on these project strategies at the International Conference on Teaching Statistics (ICOTS) in 2010.

In introductory modelling with probability and distributions, Auckland University is developing a course with similar aims to mine, as described in Section 2.3 above. To date there has been very little work done in this area, and the workshop was of great mutual benefit. Auckland University now has all my materials for this course and have requested that I return to help them develop their course.

Auckland University's Department of Statistics has also put considerable effort and resources into developing assessment strategies for large classes that use known as "traditional" methods in ways that facilitate learning and are able to assess statistical thinking (Wild et al, 1997, Forster et al, 2007). One of the strategies they have developed for their first year data analysis course is the use of certain styles of quick and summary questions. Subsequent to my visit, I have adapted this strategy and integrated it within the introductory modelling with probability and distributions approach and materials. My QUT colleague giving this course used this new strategy along with all my materials in semester 2. Her feedback on their value was supported by feedback from students during a forum.

Statisticians at the University of Auckland have also provided international leadership in developing courses on learning statistical thinking through the study and critiquing of media reports, so my visit enabled me to find out firsthand details of this approach, including its advantages and challenges.

From the workshops, intensive discussions and observation of classes, I gained insights into the department's remarkable successes in teaching statistics to such large cohorts. At the heart of their successes are: commitment by the department to quality in learning and teaching; long-term, clear and workable policies for and commitment to harmony between research and teaching objectives; collegiality, equity and constant discussion amongst staff on learning and teaching.

For the May visit, Otago University requested a seminar on developing probabilistic thinking. During that visit I also worked with the chair of ICOTS 2010 on plans.

During the May visit, it was proposed that I return to Otago University in October to give a seminar to teachers to assist with their understanding and implementation of the statistics within the new New Zealand school mathematics syllabi, and to record a DVD of the workshop for teachers that I had given in South Africa – see Section 5.12 below.

5.8 The Australian Conference on Teaching Statistics (OZCOTS) and the Australian Statistical Conference (ASC), July 2008, Melbourne

The initial planning of the Australian Conference on Teaching Statistics (OZCOTS) took place during December 2007. Because it was part of the fellowship program to hold this in association with the 2008 Australian Statistical Conference (ASC) and to coincide with visits to Australia of most of the fellowship's international collaborative team, considerable thought and discussion were required with the ASC organisers, the Statistics Education Section of the Statistical Society of Australia Inc (SSAI) and the fellowship's overseas collaborators. It was decided to hold OZCOTS as a 2-day satellite conference to the ASC on 3rd & 4th July 2008, at the same venue as ASC in Melbourne, but with the first day of OZCOTS coinciding with the last day of ASC as an associated "strand" of the ASC. Fortunately, four key overseas and two key national members of the fellowship's collaborative team were able to attend at that time, and they were all invited speakers at OZCOTS, thus providing a highly desirable and visible conference, with potential for major impact for the Australian statistics



education community. By arranging for the first day of OZCOTS to form part of the ASC, it was hoped to increase involvement in, and visibility of, statistics education. Indeed, the first invited speaker of OZCOTS was billed as a plenary address of the ASC.

The planning for OZCOTS and the setting up of the website continued during January and the publicity was launched in February. The conference committee was finalised, abstracts for contributed papers were called for, and guidelines for papers and the refereeing process were established. Notifications of acceptance or rejection of the abstracts were sent out by the end of March together with advice, guidelines and procedures for the papers. Refereeing was offered to those authors wishing to avail themselves of this service, and papers meeting the required standards through the refereeing process are designated as such in the Proceedings which have an ISBN and are available at <http://sky.scitech.qut.edu.au/~macgilli/ozcots2008/>.

OZCOTS was an outstanding success, with approximately 60 full delegates, and up to 50 ASC delegates choosing to participate in at least one OZCOTS session. After the first day, a number of the ASC delegates chose to stay on for the second day of OZCOTS. There were six keynote speakers, eighteen contributed papers and two forums. In reporting on the ASC conference, the SSAI Newsletter placed as much emphasis on OZCOTS as on the ASC. The organisers of the next ASC immediately included plans to hold a similar OZCOTS in conjunction with the ASC. OZCOTS 2008 succeeded even better than hoped in its aim to increase interest amongst research and professional statisticians in statistics education, and in bridging gaps between these groups and statistics educators. The challenge now is to maintain and develop this initiative.

The organisers of the statistical methodology strand of the ASC invited me to speak in this strand with the aim of focussing the attention of statistical practitioners and researchers on the importance of statistics education and the continuing crisis in supply of statisticians that is affecting business, industry, government and the universities across the world, particularly the English-speaking world. My paper, *Building foundations for statistician education* was very well attended and prompted considerable discussion amongst leading Australian statisticians with varied or little experience in statistics learning and teaching.

Following OZCOTS, my international collaborators, joined by Dr Chris Reading who had returned early from the International Conference on Mathematics Education in Mexico to join us, were able to visit QUT for up to a week, for intensive discussions on a range of topics including:

- international contrasts
- building on the OZCOTS forums
- models for learning to teach statistics
- resources
- mathematics versus statistics
- furthering reforming statistics education
- course structures and associated materials
- challenges in teaching statistics across school levels.

A workshop in Brisbane was held on 8th July, titled Discipline-based challenges when teaching statistics, to include my international visitors as facilitators for participants from a range of disciplines from SE Queensland universities. Despite extensive publicity across all faculties and departments in these universities, very few participants from other disciplines attended. Those who did found the workshop to be informative and interesting. Some staff made contact to say they would have liked to attend but had other commitments, but this does illustrate one of the many challenges in networking amongst all staff involved in building on foundation statistics learning in other disciplines, namely, that statistics is not their discipline of choice – learning and teaching in statistics is ancillary to their main focus in teaching.



5.9 International Association for Statistics Education (IASE) 2008 Roundtable in Mexico

I had also received an invitation to give a presentation on the Interplay of Probability and Statistics in Teaching and Teacher Education at the International Association for Statistics Education (IASE) 2008 Roundtable in Mexico on *Statistics Education in School Mathematics: Challenges for Teaching and Teacher Education*. Unfortunately this clashed with the dates for the ASC and OZCOTS. However I proposed that my presentation be joint with Dr Delia North who had already arranged to attend the Roundtable and the International Conference on Mathematics Education to be held the following week at the same venue. This proposal was accepted and I wrote the paper and presentation to be delivered by Dr North, titled *Strengthening the interplay of probability and statistics in teaching and in training the teachers*.

Dr North subsequently spent some time at QUT as a fellowship international collaborator, attended classes and inspected students' work in data investigation projects and in modelling with probability and distributions. She obtained copies of all my materials for these courses to form the basis of revisions of the courses in her university. We will continue to work on our mutual interests in developing probabilistic thinking in statistics.

5.10 Learning to teach statistics in higher education

Towards the end of February, I took part as usual in the 2-day program of tutor training in mathematics and statistics run by myself and colleagues in QUT's School of Mathematical Sciences. In my visits to other universities and other countries, I found that such programs and a systematic approach to mentored experience are increasingly of interest. In 2008, we included for the first time a segment on learning to mark, as suggested by participants in evaluations of previous tutor training programs.

Because of the extent of interest in such a program at all universities I visited, from staff and postgraduate students, I decided to conduct interviews with academic staff and sessional tutors on what they thought was important in learning to teach mathematics and statistics at the tertiary level, and what are the differences between learning to teach mathematics and statistics. These interviews formed the basis of a contributed paper, *Learning and developing higher education teaching in statistics*, given in September in the UK at the CETL-MSOR conference, Teaching and Learning of Mathematics, Statistics and Operational Research, held at the University of Lancaster.. Feedback from this will be used to further develop the paper.

Every interviewee commented on the central importance of learning to teach mathematics and statistics through a mentored progression of one-to-one assistance to students, to tutoring small groups, to tutoring groups within a larger class, to lecturing small groups and assisting more experienced lecturers. The unanimous opinion was that nobody should be asked to lecture without experience as a tutor, and that tutoring should be viewed as part of professional development for university teaching staff. Comments on learning to teach statistics included:

- Lots of complicated ideas in stats – scaffolding is subtle
- Inference vs. implication – inference has probabilistic basis
- Concept of error of estimate is fundamental
- Statistics procedures point direction – no definite answers
- Greater need for story and pictures
- Need rich and complex datasets and contexts
- Examples core of teaching
- Prior reading (by students) not advisable – can't grasp concepts – but preliminaries that capture prior knowledge good (for meaning of preliminaries, see MacGillivray, 2006)
- Important to see variation in datasets and contexts
- Learnt understanding of statistics through teaching service courses



5.11 Detail of activities and outcomes/influences: UK

During September, I visited the Mathematics Education Centre at Loughborough University, the Royal Statistical Society's Centre for statistical Education in Nottingham, attended the CETL-MSOR Conference at the University of Lancaster as described in (5.10), and visited the Statistics Department of Glasgow University.

At the University of Loughborough, I worked with Dr Richard Gadsden on responses to a statistical reasoning questionnaire by Australian students in science and engineering, and by UK students in engineering and economics. The students took this questionnaire before their first course in statistics at university. The analysis will indicate similarities and contrasts between the countries and the faculties, facilitating insights into students' statistical needs and input into curricula design at the school/tertiary interface.

I also worked with Professor Tony Croft, Director of the Centre and of Sigma, the Centre for Excellence in Mathematics and Statistics Support, on research that is indicating the needs of capable students in learning support and what is important for mathematics and statistics students in their learning environments. This work contributed to an invited paper *Learning support and students studying mathematics and statistics* to appear in IJMest in 2009. Collaboration will continue with Professor Croft on developing an evidence-based culture in learning support, and on support needs across the ability spectrum. Professor Croft plans to visit Australia and QUT in October, 2009.

At the University of Glasgow, I continued my ongoing collaboration with Professors Adrian Bowman and John McColl on developing web-based resources and curriculum design for learning statistical thinking. I worked on Model Choice, with which I have been involved for a number of years (McColl et al, 2007) and with which Dr Therese Wilson and I will be assisting in trialling with students in 2009-2010. I also reviewed and assisted with the trialling of a new resource called TestChoice or StatChoice, which has been made available to me for trialling in Australia. This resource arose from concepts developed during one of my previous collaborative visits to the University of Glasgow in January, 2007, so it was a great pleasure to see it coming to fruition. During my visit to Glasgow, I attended classes for life science students and for second year and honours students in statistics, and was involved in discussions on the effects of the UK's Research Assessment Exercise on learning and teaching.

5.12 Activities related to statistics in school syllabi

Throughout the fellowship program, came opportunities and requests for presentations, workshops and input on the teaching of statistics in school curricula. The workshop for teachers in South Africa was based on workshops that I have given to many professional development events or teacher conferences in Brisbane and regional centres in Queensland. As stated above, this workshop has been recorded as a DVD by the educational resource development group at Otago University. They are developing DVD resources in statistics and mathematics for educational evaluation purposes, and this DVD will form part of these resources. They are oriented for teachers in New Zealand and Australia.

In November, 2007, I delivered an invited address to students and their families at the Queensland award ceremony for the Australian Mathematics Trust, and in May, 2008, I delivered a speech for a mathematics awards evening.

In August, I presented a keynote paper at the Workshop on Integrating Statistical Ideas into Mathematics, organised by the Mathematics Association of NSW and the NSW Branch of the Statistical Society of Australia (MANSW/SSAI (NSW)), in Sydney. The paper's title was *Statistical lessons from two decades of working with teachers and syllabi developers*.

During my visit to the UK in September I was asked to review and audit materials for a proposed Royal Statistical Society certificate in teaching statistics up to pre-university level.



During the fellowship I was invited to prepare a paper for the Queensland School Authority's 2009 Senior Schooling Conference. The paper's title was *Building foundations in statistical thinking for future learning*

5.13 Development of websites of resources

An audit of the main international internet resources for teaching statistics was carried out during December, 2007, to February, 2008. This contributed to the information about the types and nature of resource needs that I gradually built up during my visits throughout the year.

During the fellowship, preparation of datasets and materials from the many student free-choice data investigation projects was undertaken for the development of a website of authentic and rich datasets with notes and teaching comments. Examples of these were included in seminars and discussions during the above visits to obtain feedback to ensure the usefulness of the resource. With the assistance of Dr Crawford, this website was designed and established during November, 2008, to February, 2009. Feedback was obtained from Glasgow University collaborators during the design process. Extending and maintaining this website continues and will be an ongoing commitment. The website is <https://teaching.sci.qut.edu.au/data2teach/>

A second website on teaching tips is being designed, and its development is ongoing.

5.14 Forum on Building Networks in Statistics Education

In February, 2009, a forum was held at QUT with the aim of building networks in statistics education in Australia and New Zealand. The forum was widely publicised amongst statistical professional and educational groups, and the New Zealand Statistics Association (NZSA) and each state branch of the Statistical Society of Australia (SSAI) were also invited to nominate two delegates with expenses paid. Apart from a few reports from the fellowship, the IASE, SSAI and NZSA, the forum aimed to be a discussion and working forum. It was designed for approximately 60 participants, which was the number who attended. Topics covered were:

- Tertiary curricula commonalities
- Roles and links with and between professional societies
- Statistics in school and the national curriculum
- Models for building a network
- Interactions with other disciplines
- Postgraduate support across disciplines
- Interactions with employers
- Building on the SSAI review
- Support for school-teachers
- Ways forward.

Principles for statistics in school syllabi were developed during the forum. Following further input and review by participants, the ABS, SSAI, NZSA and Statistics NZ, these principles were endorsed and submitted to the national curriculum committee. Forum participants also wrote and submitted individual input to the national curriculum. Further reports and activities to develop an Australian and New Zealand network in statistics education are ongoing.

A summary of part of the evaluation of the forum is provided as an appendix.



6. Some key findings

Many of the outcomes, results and influences are described above in association with the environments in which they occurred or from which they arose. Many others are, or will be, incorporated in publications. Many of the findings were confirmatory of my previous views and knowledge, but with added depth and breadth. Some general findings include:

- Statistics education reform DOES need to expand its vision, move outside its boxes and incorporate more statistics
- My strategies are at the cutting edge in statistics education and are part of leading developments
- “Seeing through students’ eyes” is a never-ending learning curve that requires ongoing interaction with students
- Differences and influences of educational culture, environment and student expectations are significant greater than generally understood, and can be discovered through onsite participation
- There’s no single right first course in statistics
 - Focus should be on principles
 - Careful structuring and flow of story so important
 - Identification of, and alignment with objectives needed
 - Integrated, developmental, purposeful learning and assessment packages are essential
- Collegiality between staff and students is of key importance for learning in maths/stats
- Creating learning environments is also essential for learning in statistics
- Collegiality in teaching is more important than teaching teams
- Tutorials and practicals are pivotal for learning to teach
- Practicalities of learning to teach need more attention
- Tutorials/practicals and lectures are equally important for student learning
- Different worlds in statistics need better inter-bridging and understanding and respect
 - main ones are statistics research; learning and teaching practice and scholarship; educational research
 - this is one of my aims for my presidency of IASE
- Better understanding is needed of the roles of mathematics in statistics
 - Compare thinking with thinking, procedures with procedures
 - Conflict and dogma are inhibiting
- More respect is needed in the tertiary sector for the everyday hard work of teaching for student learning

7. Materials, websites and publications

Set of materials for teaching introductory data analysis, oriented to experiential learning of data investigations. (Available on request)

Set of materials for teaching introductory modelling with probability and distributions, oriented to problem-solving and everyday processes. (Available on request)

OZCOTS <http://sky.scitech.qut.edu.au/~macgilli/ozcots2008/>.

Data2Teach <https://teaching.sci.qut.edu.au/data2teach/>

Tips4Teaching under development

DVD MacGillivray, H.L. (2008) *Developing foundations in statistical thinking in data and*



chance, Otago University Series for teachers.

Model Choice (with John McColl, Bradley Payne)
<https://teaching.sci.qut.edu.au/modelchoice>

MacGillivray, H.L. (2009) Learning support and students studying mathematics and statistics
IJMest 40 (4), 455-472.

MacGillivray, H.L. (2008) The roles of assessment in learning in statistics and mathematics
In Green, D. (ed) The Proceedings 2007 CETL-MSOR Conference, 90-100, The Maths,
Stats and OR Network, Birmingham.

MacGillivray, H.L. (2008) Examples from an introductory course in developing probabilistic
statistical thinking: part 1, MSOR Connections 8(1), 7-10.

MacGillivray, H.L. (2008) Examples from an introductory course in developing probabilistic
statistical thinking: part 2, MSOR Connections 8(2), 2-5.

MacGillivray, H.L. (2010) Variety in Assessment for Learning Statistics. In *Assessment
Methods in Statistical Education: An International Perspective*, (eds) Neville Hunt, Flavia
Jolliffe and Penny Bidgood, Wiley (to appear).

MacGillivray, H.L. and Mendoza, L. (2010) Teaching through projects/investigations, with
Lionel Mendoza. In *Statistics education and School Mathematics: challenges for teaching
and teacher education*, (eds) Batanero, C., Burrill, G., Reading, C. and Rossman, A.,
Springer (ICMI Series) (to appear).

MacGillivray, H. L. (2009) *Building foundations in statistical thinking for future learning*,
Senior Schooling Conference 2009, Brisbane.

In preparation or ongoing

IASE August 2009, South Africa, *Some principles of flows and steps in designing tertiary
statistics curricula for learning*, with Michael Martin.

ISI invited paper for August 2009, South Africa *Similarities and contrasts in learning problem-
solving in statistical data analysis and modelling*.

ICOTS8 invited paper *Student discovery projects in data analysis*, with Mike Forster; due
October, 2009

RSS invited paper *Constructing environments for early learning in statistical thinking in
higher education*, with Helen Johnson; September, 2009.

MacGillivray, H.L. (2011) *Utts and Heckard Mind on Statistics*, Cengage Learning Australia
(in preparation).

Investigating statistical reasoning at school/tertiary interface, with Therese Wilson.

Contrasts in statistical reasoning on tertiary entry, with Richard Gadsden.

Mathematical and statistical thinking, with Chris Reading.

Towards a culture of evidence in learning support, with Tony Croft.

Model choice on the web, with John McColl.

Student learning through PPDAC at different levels, with Stefan Steiner.



8. Some challenges encountered

There were some main challenges encountered and in most, the challenge lies in balance, and the difficulty lies in time demands and effort fragmentation.

One major challenge is finding an appropriate person to be seconded to replace the senior/national fellow. The person not only needs to be capable of replacing the fellow but also able and willing to be part of the teaching team of whom the fellow is a part, and usually a leader. Collegiality in a teaching team is essential, and disruptions during a fellow's tenure of a fellowship can do long-lasting damage.

Another challenge is balance of the fellow's fellowship with past and future commitments. Despite the secondment of a professor to do my teaching, the fractional employment of a lecturer level A, spreading my academic duties across staff, a year of lead time to prepare my School for my absence, and the willingness of my colleagues to relieve me of all responsibilities, it is neither possible nor desirable for someone with my experience, expertise and seniority in learning and teaching not to be asked for help, advice or input into plans and strategies. It is also essential to be involved in this, even if minimally, because of continuity and consistency in the fellow's normal duties beyond the fellowship. This is simply part of the challenge of an ALTC senior/national fellowship and must be accepted as such.

Another challenge is in the organisation of travel, visits, meetings, seminars and conferences – for both the fellow and the international collaborative team. Because this requires cooperation with people who are themselves leaders in learning and teaching, and with teaching teams during teaching times, this requires both logistical and diplomatic skills. Again this is an expected part of an ALTC senior/national fellowship. I commend the ALTC's understanding of this challenge as demonstrated in the revised guidelines for National Teaching Fellowships.

The third main challenge was not expected and has both benefits and burdens. This is the challenge of balancing the extra requests and opportunities that have arisen owing to the prestige resulting from the award of the ALTC senior/national fellowship. Australia can feel very satisfied that the profile and standing of learning and teaching has been, and continues to be, significantly raised through the efforts of the ALTC.

Another ongoing challenge for the entire tertiary sector, is, the balance between research and learning and teaching. There is need for greater respect and understanding of the demands and importance of teaching that has commitment to student learning as its top priority.

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Appendix

2009 Forum on Building Networks in Statistics Education

% responses (30 responses returned)

<i>The forum was relevant and helpful for me in my work.</i>				
<i>Strongly Disagree</i>	<i>Disagree</i>	<i>Neutral</i> 7%	<i>Agree</i> 62%	<i>Strongly Agree</i> 31%
<i>The content of the forum was relevant to building networks in statistics education.</i>				
<i>Strongly Disagree</i>	<i>Disagree</i>	<i>Neutral</i>	<i>Agree</i> 42%	<i>Strongly Agree</i> 58%
<i>The structure of the forum was relevant to building networks in statistics education.</i>				
<i>Strongly Disagree</i>	<i>Disagree</i>	<i>Neutral</i> 7%	<i>Agree</i> 54%	<i>Strongly Agree</i> 39%
<i>4. There was too much discussion</i>				
<i>Strongly Disagree</i> 19%	<i>Disagree</i> 43%	<i>Neutral</i> 27%	<i>Agree</i> 11%	<i>Strongly Agree</i>
<i>I plan to share the thoughts and discussion outcomes of the forum with my colleagues.</i>				
<i>Strongly Disagree</i>	<i>Disagree</i>	<i>Neutral</i> 3%	<i>Agree</i> 62%	<i>Strongly Agree</i> 35%
<i>Overall the forum provided a valuable contribution to statistics education</i>				
<i>Strongly Disagree</i>	<i>Disagree</i>	<i>Neutral</i> 3%	<i>Agree</i> 62%	<i>Strongly Agree</i> 35%

