STEMS2016

Putting Statistics into STEM in the Age of Data

A Colloquium and Workshop organized by the Statistical Society of Australia, 2–3 June, 2016, at University of Technology Sydney

Final report

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Version: 31 October 2016

Sponsored by

Statistical Society of Australia

Australian Mathematical Sciences Institute

ARC Centre of Excellence in Mathematical and Statistical Frontiers

University of Technology Sydney

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Executive Summary

It is widely recognised, both in Australia and overseas, that there is a large and growing gap between the requirements of government, business, industry and educational institutions for statistically qualified graduates and actual production of such people.

In response to this, the Statistical Society of Australia staged a two-day event, STEMS2016 in June 2016 to explore current and emerging workforce needs, and to make a start on developing appropriate responses. The event comprised a one-day conference at which senior representatives of a wide range of interested groups provided a survey of the key issues, followed by a day in which working groups started to develop some plans to transform Statistics education at schools, at the undergraduate level and at postgraduate level.

This report provides a summary of the presentations at the conference, and of the initial ideas that emerged from the working groups. Most of the proceedings from the conference were captured by video and are available via the STEMS2016 website.

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1. Introduction

The last few years have seen unprecedented growth in the availability of data in most areas of human endeavour. Whole branches of Statistical Science[1] have been developed to allow corporations to transform the way marketing is conducted, to drive scientific progress in areas such as Bioinformatics, and to inform decision-making at all levels in governments and industry. Further, the scale and complexity of much of these data are beyond the capability of a single computer to manage or a single individual to analyse.

These realities generate a very significant imperative to ensure that there is an adequate supply of people entering the workforce who are equipped to handle the new statistical challenges. There is a compounding factor: on the evidence available, demand for statisticians is not only outstripping supply, but the situation is worsening. A 2011 McKinsey report on the situation in the USA projected a shortfall of 140,000 – 190,000 qualified Statistics graduates by 2018. The situation in Australia is likely to be proportionately far worse.

Thus it is becoming increasingly urgent that statistical educators adapt to the real-world imperative of ensuring an adequate supply of statisticians prepared to meet this need. This challenge raises critical questions:

- How will the Australian educational system respond to meet this need?
- What shape must the Statistics curriculum take, both at late-secondary school and tertiary levels?
- How can said curriculum be supported and succeed at addressing this national and international need?

Paradoxically, the growing gap between the supply and demand for a statistically skilled workforce is arising in the context where mathematics education is in trouble in Australia, with declining performance and declining numbers of enrollments in higher level mathematics training. The Australian Academy of Science recently announced the Decadal Plan (DP) which outlines in broad strokes what actions are needed to address these issues[2]. STEMS2016 was in large part a response from the statistical community to develop an operational plan to progress the challenges articulated in the Decadal Plan in terms of statistical education and training.

[1] As well as other disciplines!

[2] https://www.science.org.au/support/analysis/decadal-plans-science/decadal-plan-mathematical-sciences-australia-2016-2025

2. Organisation of STEMS2016

In response to this challenge, the Statistical Society of Australia organised a two-day event at the University of Technology Sydney with the twin purposes of:

1. Initiating a conversation between leaders in secondary education, tertiary education, government and industry about how to re-imagine school-based Statistics curricula especially for Years 11/12 and university degrees, both undergraduate and postgraduate, in data-dependent disciplines to create the next generation of Statistics and Data Science graduates; and
2. Making a start on planning the way forward.

STEMS2016 comprised a one-day open colloquium followed by a one-day planning workshop.

STEMS2016 was promoted widely in Australia and New Zealand, attracting over 100 participants from all areas with an interest in statistics education, from primary school, secondary school and academia to government and industry. Financial sponsorship was provided by the University of Technology Sydney, the Australian Mathematical Sciences Institute (AMSI) and the Australian Research Council Centre of Excellence in Mathematical and Statistical Frontiers. Along with these three financial sponsors, it was strongly supported by a number of other organisations including (in alphabetical order):

- AAMT (The Australian Association of Mathematics Teachers Inc.)
- ACARA (Australian Curriculum, Assessment and Reporting Authority)
- Commonwealth Bank of Australia
- BOSTES (Board of Studies Teaching and Educational Standards NSW)
- Statistical Society of Australia
- The Office of Prime Minister and Cabinet
- The Office of the Chief Scientist

3. The One-day Colloquium

The colloquium had two half-day components.

The morning session was devoted to presentations aimed at providing participants with a broad context within which this educational transformation will need to take place. Speakers from scientific, business, governmental and educational backgrounds presented a variety of perspectives. Topics and speakers for the morning session were:

Statistical Education and Educating Statisticians: Producing wine connoisseurs and master winemakers	Professor Xiao-Li Meng, Dean, Graduate School, Harvard University
Statistics – A National Perspective	Dr Roslyn Prinsley, National Adviser, Science & Mathematics Education and Industry, Professor Alan Finkel, Chief Scientist, Australia
Commercial perspectives from the Finance industry	Mr Hamish Treleaven, EGM Portfolio & Market Risk Management, Commonwealth Bank of Australia
A government / public data perspective	Ms Helen Owens, Assistant Secretary, Public Data Branch, Office of Prime Minister & Cabinet
Critical issues to be addressed to transform statistics education– a school curriculum perspective	Mr Robert Randall, CEO, Australian Curriculum, Assessment and Reporting Authority
A Statistician's perspective	Professor Louise Ryan, UTS and Chief Investigator, ARC Centre of Excellence for Mathematical and Statistical Frontiers
Statistics Education in Australia: We need a revolution	Professor Nicholas Fisher, a Past President of the Statistical Society of Australia

Videos of these presentations (except for that of Ms Owens) can be found at https://stems2016.com/presentations-videos/. Details about the speakers and abstracts of their presentations are provided in Appendix 1. Key points from their presentations can be found in Appendix 2.

The afternoon session commenced with a panel discussion, with panelists being asked to identify the critical issues that would need to be confronted if the ultimate aims of the event were to be realised. This was followed by a floor discussion. Panelists for the afternoon session were:

Professor Murray Cameron	Director, Industry Doctorates, at the University of Technology Sydney
Dr John Henstridge	President, Statistical Society of Australia

Dr Peter Howley	Chair, Statistics Education Section, Statistical Society of Australia
Dr Jose Martinez	Senior Predictive Modeller, Qantas Loyalty.
Professor Geoff Prince	Director, AMSI
Professor Jacqui Ramagge	Head of the School of Mathematics and Statistics , University of Sydney
Ms Anna Wethereld	Mathematics and Numeracy Inspector, BOSTES

Videos of the panelists' comments can be found at https://stems2016.com/panel-discussion-video/.

A number of common threads and ideas emerged from the first day's presentations. Almost all the speakers and panellists touched on some of the global trends that are influencing the direction of statistical education at the present time. For example, although it is abundantly clear that Statistics is playing a central role in driving the current innovation agenda, the role of statisticians tends to have been lost within the broader mantle of Data Science. Indeed, new specialty fields such as Machine Learning and Analytics are emerging in response to the changing environment in an effort to fill perceived skills gaps (see, for example, the recent report from CSIRO's newly established Data61, "Tomorrow's Digitally Enable Workforce"). In the finance world, for example, it is increasingly common for companies to appoint a Chief Data Scientist and to establish a Data Scientist role related to improving customer service through clever analysis and interpretation of customer databases. Cyber security is increasingly important in this context as well. The related Chief Data Officer/Data Officer role is emerging in some industries to deal with data management strategies and data architectures. Whilst it might seem obvious that Statistics is important, it is by no means the whole story. To be competitive in modern day industry, a statistician's toolbox needs to be significantly expanded to encompass new skills in areas such as machine learning and automation, cyber security and encryption, version control and distributed data systems. It can be argued that the broader and more fundamental need is for Data Science, of which traditional statistical skills are just one, albeit an important part.

A number of speakers touched on the fact that modern-day workforces need people who not only have good technical skills, but also the so-called "softer skills" related to communication and collaboration. People also need some domain knowledge, for example, commercial acumen for those working in the business domain, or medical knowledge expertise for people working in health. Communication skills are important for not only working with customers and clients, but also for communicating with collaborators and with senior management, funders funding agencies, and so on. In general, there was a sense that successful statisticians will be those that have a general common sense and an ability to engage with and understand

the context and the key questions of interest. Of course this concept is not new, but ever more important in today's information age.

Worldwide, there is compelling evidence that supply of such people with this broad set of skills is lagging well behind demand, especially for people who have the combination of technical and "soft" skills as described above. Consequently, people from other fields outside Statistics, such as Computer Science, and Physics, are stepping in to do statistical analysis, but without the proper background and education. Incremental change won't address this problem. Disruptive change is needed for statisticians to claim their place in the Data Science revolution.

Several presenters spoke to the importance of having a broad broad-church approach to statistical education. By focusing too narrowly on training specialists, the professional risks becoming marginalized. Furthermore, it is critical to think about innovative ways to reach the large population of students who are destined to specialize in various applied areas, but who need a working knowledge of Statistics. In other words, we not only need statisticians, but also scientists who can think statistically. Xiao-Li Meng from Harvard used an analogy that many workshop participants appreciated and referenced over the course of the workshop. He contrasted master wine makers with wine connoisseurs and wine lovers: one does not need to be a master in order to appreciate the product. By engaging with other relevant disciplines to help foster statistical literacy more broadly, we create a better understand and appreciation of what the specialist statistician has to offer. Providing effective broad-church education is indeed a great challenge, but it is an avenue where the rewards are potentially great.

Several presenters noted that in teaching Statistics, there is a critical need to excite students about Statistics well before Years 11 and 12. Vital to attracting more students is motivating them to "like Statistics" and to recognize it can be relevant and fun. Teaching at the introductory level is more likely to be effective if it starts with interesting and appealing applied questions relevant to what's important to them in their daily lives, and then leads the students almost indirectly to learn about statistical design and analysis.

Communication was identified as a key issue in a number of different contexts. We have touched already on the fact that industry desperately needs workers who are not only technically strong, but who can engage with real world applications, work in teams, and so on. Communication is also problematic in the sense that there tends to be a mismatch between what industry needs and what the job advertisements actually specify. Computer scientists have been more effective in articulating the specific skills needed within particular roles, although perhaps to the extent of downplaying or even neglecting the statistical content needed for effective Data Science. They have talked about the concept of "CS plus X" where X might be commerce or medicine or some other applied domain – that is, Computer Science has highlighted not only domain expertise but explicit knowledge in their own discipline. Why don't we do that more effectively in Statistics?

In addition to these global challenges facing the Statistics profession generally, Australia faces a number of specific challenges. At the present time, the Australian Mathematics and Statistics education system is in trouble, with declining performance relative to international standards and declining interest on the part of students. Some new initiatives are underway in curriculum development, but more needs to be done.

Fragmentation and lack of critical mass is a major issue for Australia. Our small population relative to our large land mass is only part of the problem, since Statistics departments at even the major universities tend to be small and folded into larger entities, usually Mathematics but sometimes also Physics and Chemistry, or business disciplines.

The Australian research funding model makes it very difficult to build strong capability in Applied Statistics. ARC funding is flat or declining in real terms and generally provides little support for collaborative research in the statistical sciences. Applied Statistics, along with interdisciplinary research in general, easily falls between the cracks. Unlike the research funding model in the United States, ARC and NHMRC grants do not generally support senior level salaries. This makes interdisciplinary collaboration quite challenging. University reward systems and faculty silos create disincentives for collaboration. It is particularly important to engage with the computer science and engineering disciplines, both in terms of teaching and research, but the current funding and incentive models work in precisely the opposite direction.

However, the speakers were not just preaching doom and gloom: they collectively had a number of suggestions for things that can be done. A number of these fell under a broad umbrella of what might be termed *advocacy*. Others related to specific ideas on how to enhance education and training at all levels, from K- 12, through to undergraduate and postdoctoral training levels.

Advocacy

- It is clear that the statistical profession needs a cultural revolution. Statistics is a powerful enabling discipline, especially in this modern information age. However it needs to be far better at articulating this so that it can be valued, as both a collaborative endeavour and (discipline/profession and) professional career path itself. It would be helpful to utilise modern marketing and communication tools to improve the visibility and general appeal of the Statistics profession. Such efforts could help market Statistics to students more broadly. A key focus must be to reach students in their early and formative years, so it will help if schools and teachers are better informed. Publications like *Significance* and *The Conversation* are a start. The SSA Professional Accreditation program can be a helpful mechanism for providing a framework for acknowledging and promoting professional practice in Statistics, much like an Accountant seeks to achieve CPA; however, this must be addressed in tandem with showing why such is required.

- There is a pressing need to advocate for change within the University environment to recognise teaching performance more effectively. This needs to go beyond lip service and teaching awards, and to translate into tangible actions to do with appointments and promotion in both teaching and research domains. Similarly, there is a need for advocacy about the importance of interdisciplinary and applied work.

Teaching and Education

- Continued effort is needed to emphasise the importance of Mathematics and Statistics in K-12 education (*e.g.* all school principals need to be educated to be aware of this, a point emphasized by Roslyn Prinsley). Some good things are happening in terms of enhancing the school curriculum in years 10 through 12, but more needs to occur. As part of such efforts, it is critical that teachers be valued and provided with the training and support that they need. It will be important to build on the work ACARA has done for years K – 10.
- Attention is needed to on how to motivate students to want to learn more about Statistics rather than focussing too much on theory which will turn many of them off. Schools should be uniting students' passions and interest in investigation with the need for Statistics. Introductory courses should emphasize the transformational use of data. S tudents in introductory courses should learn about the broader implications and interdisciplinary relevance of Statistics. But then schools need to have the resources in place to better inform, and then identify and nurture talent as it emerges. It makes sense to think in terms of two intertwined streams of statistical education, one for mathematically talented students who decide to specialise in statistics and the other for the majority of students who will end up in other career paths, but for whom a working knowledge and appreciation of statistical thinking is important in their daily lives.
- The need for Statistics and, more generally, some understanding of data is so ubiquitous that it should be required of all university graduates.
- Statistical education within the postgraduate research domain is very important: today's PhD students and postdoctoral fellows are tomorrow's leaders. Research trainees not only need to be equipped with cutting-edge technical skills; they also need to have strong communication and collaboration skills. They need to emerge as creative problem solvers. There are several avenues that could be pursued to help achieve this, including
    - Engaging more effectively with industry. Efforts such as the Industry Doctoral Training Centre (IDTC) being offered through the Australian Technology Network is a great model, but it needs to expand and become more mainstream.
    - Creating and expanding funding models to support the kinds of collaborative research environments that exist in the US, the UK and some other countries. ARC and NHMRC need to be urged to more effectively support innovative interdisciplinary efforts. However at the same time, we also need to educate our own discipline to value such

work appropriately. Unless interdisciplinary proposals are reviewed in a context in such work is seen as fundamentally valuable, such work will not get funded.

- Statistical education within government is already receiving significant attention [Helen Owens' presentation, point 5, in Appendix 2]. However, this is not well-publicised outside the public sector.
- It is important to be aware of and learn from best practice overseas, including what's happening at leading universities, as well as in Government. There are many excellent initiatives under way, for example, the Data Science Accelerator Program in the UK, designed to empower government agencies to transform themselves into intelligent users of their own data.

4. The One-day Workshop

Workshop participants divided themselves into three working groups on school, undergraduate and postgraduate education. Each group identified (with varying degrees of detail) a number of recommendations and some preliminary thoughts on how to take the work forward. Summary information is provided below; more detail can be found in Appendix 4. An important first step is to turn each of these sets of recommendations into action plans. A draft proposal in relation to Schools is currently under development.

Any new programs and initiatives will need to be developed in consultation with – and, in some cases, the involvement of – a number of stakeholders, all of whom have a vested interest in the outcome. Depending on the educational level (school, undergraduate, postgraduate), the key stakeholders may include:

- Relevant professional societies – SSA, AAMT, Australian Computer Society, …
- Universities
- Major employers
- Academies (AAS, ATSE)
- Program collaborators – external groups partnering in the provision of the program.
- Government/Public sector, *e.g.* ABS, ABARE, CSIRO
- Prospective students
- Data61 and the machine learning , analytics and data science communities Further, attention needs to be paid to ensure harmony between a student's skills and knowledge capabilities on graduating from one educational stage with the entry requirements for the next stage.

There is an important public communication aspect to each of the three stages.

A: Key points to emerge from the school working group

ACARA's K – 10 Mathematics curriculum[3] contains a reasonable amount of statistical content. There is a core concept at the heart of the materials to be presented each year, namely, the paradigm of the process of statistical investigation: *the scientific process of learning from data*. The key steps are

1. plan the investigation
2. collect data
3. analyse the data, *e.g.* explore the data and summarise the information
4. draw conclusions
5. communicate the results appropriately

[3] http://v7-5.australiancurriculum.edu.au/mathematics/curriculum/f-10?layout=2#page=1

A number of statisticians have worked with ACARA on the Statistics component of the national Mathematics curriculum for Years 11 and 12. From this, it has become evident (at least to the statistical community) that a separate 2-Unit course in Statistics combined with appropriate computing skills, knowledge and practical knowhow is needed to attract students to the subject and instill in as many as possible of them a strong desire to learn more at university. There are two strands to this:

a) Students with strong interest in applications could learn a substantial amount of Statistics without necessarily requiring strong mathematics backgrounds –2-Unit Mathematics should suffice. Such students may well wish to undertake further Statistics study at university; alternatively, they may pursue Science, Social Science, Engineering, Medicine, Business Studies, or some other area, in all of which a sound knowledge of Statistics will be of great value.
b) It is, of course, also of interest to attract more mathematically-inclined and adept students, who can be accommodated by additional coverage of more mathematically challenging statistical theory. Nevertheless, this group should also be exposed to the intrinsic underpinning basis of Statistics, learning from data and understanding the nature of variability and how we may account for such.

*Critically, for **both** strands there should be a strong emphasis on learning from data.* Thus, at this level, students must gain significant experience in gathering and working with data, particularly through engaging in real projects, so that the whole statistical paradigm can be practised and mastered. What they are taught should reflect current sound statistical practice (which implies, *inter alia*, that the use of computers is essential and that the development of appropriate programming skills is vital).

For both strands, it is also imperative that the subject be taught in such a way as to instill a passion for learning and practising Statistics. Further, the future pathways to rewarding professional careers involving Statistics have to be made evident. These requirements lead to a Critical Success Factor (CSF): *the need for teachers of Statistics at this level who understand the subject and can teach it with enthusiasm (*see pp27-29 in article to Science Teachers of NSW at https://files.secureserver.net/0sb5PbfXQtnBEU). This CSF informs the second element of the action plan – namely, that the professional development/training of teachers who teach Statistics that empowers them to effectively teach the subject needs to be provided.
We see these two actions – establishing a 2-Unit course in Years 11 and 12, and teaching teachers – as being critical to attracting far greater numbers of students to Statistics, either as specialists or as knowledgeable users, and so doing something to diminish the huge gap between supply and demand that was emphasized by the speakers and panelists during the Colloquium. In response, a specific initiative is being developed in response to these needs.

B. Key points to emerge from the university undergraduate working group

The working group articulated two principles that should underlie any future developments for undergraduate training that includes Statistics as a key component.

- *Principle 1:* The desirable skills/attributes of any Statistics graduates need to include the capacity to frame, understand and solve real problems using data. The problems can arise within any domain, and domain context is critical to arriving at practical and useful solutions.
- *Principle 2:* University offerings in Statistics need to be nuanced and diverse, to match the diversity of backgrounds and interests of the students we teach. Further, access to Statistics courses needs to match the needs and abilities of students in the disciplinary cohorts that use Statistics.

The Working group developed a number of recommendations for undergraduate curricula, including

- retaining flexible mathematical and statistical prerequisites for entry into Statistics degree programs at university
- development of central data repositories that can be used as a teaching resource. While some such repositories exist already (e.g. StatLib, based at Carnegie-Mellon University and the Australian Data Archive, based at the Australian National University), they do not provide enough practical guidance on how they can be effectively used in teaching.
- a first course in Statistics based on a problem-and-data-first approach
- collaboration on examples of best practice and sharing of resources
- emphasis on the use of software for visualisation
- the importance of pre-requisites for second and later-year courses of study, to support teaching of methodology with an appropriate level of mathematical rigour
- the need for cross-disciplinary approaches to degree structures to promote the "Statistics plus X" model– *e.g.* double-degree courses of study, for instance with one half of the degree focussed on Statistics and the other on another discipline (Biology, Computer Science, Mathematics, Psychology, …)
- mechanisms for supporting teachers of first course convenors, such as a first course convenors' group. This could potentially be identified as a focus of an ongoing STEMS group.
- the broader role of SSA in supporting the teaching of Statistics at university, for example in relation to recognition of outstanding teaching and re-visiting professional accreditation.

C. Key points to emerge from the university postgraduate working group

A range of postgraduate programs is envisaged:

- Honours degrees
- Graduate Diplomas
- Master's degrees (by coursework or by research)
- PhD (taken to include professional doctorates as an overall label)
- Postdoctoral training
- Continuing Education

The design of new programs needs to take account of the varying destinations for graduates:

- decision-making and management roles, where they will be users and interpreters of statistics and so will need a sophisticated knowledge of statistics and research to inform their jobs as strategists, managers, policy makers, and so on. A Graduate Diploma could be a good baseline degree program for providing this kind of training.
- careers as analysts, involving technical problem formulation, modelling and analysis of data (mostly with established methods) and, importantly, communication of results. A Master's degree could form the basis for such roles.
- pursuing innovation with a view to taking up academic appointments or research positions in industry and Government. Such roles would generally require coursework- and thesis-based Master's, PhD and postdoctoral training programs.
- School teaching. Continuing education for teachers with non-Statistics backgrounds.

Each of the programs should be designed to develop relevant core capabilities in its graduates, relating to professional development, scientific problem solving, principled statistical thinking and intuition, computational skills, and scholarly development. Expertise in modern computer science, programming and data management is seen as a critical element of the toolbox that is essential to success as a modern day statistician or data scientist. The extent to which a given capability is needed will vary between programs. The Working Group identified a number of characteristics that would be required to ensure that programs would be attractive both to prospective students and to prospective employers of program graduates.

The lack of critical mass within the Statistics discipline suffered by the majority of Australian Universities means that effective cross-institutional collaboration will be essential. Planning efforts going forward should build on established successes such as the Biostatistics Collaboration of Australia and the AMSI Summer Program.

5. Where to next?

The first steps will be to establish two committees.

A **Planning Committee** will have the task of keeping this work going. Members should include the facilitators of the three working groups, as well as a representative from each of the principal stakeholder groups:

a. SSA (*e.g.* Chair of Statistics Education Section, if not included above)
b. NZSA
c. ACS
d. AMT
e. AMSI
f. Data Science – other?
g. BOSTES???
h. ACARA???

Their tasks will include development and implementation of a detailed Operational Plan for each year, together with regular reporting to key stakeholders. They may have some responsibility to assist in seeking financial support for their activities, and will have budgetary and financial responsibilities.

A high-level **Standing Committee.** This committee needs to consist of senior, influential people representing the principal stakeholder groups, yet kept as small as possible. Suggested membership (all *ex officio*):

a. President of SSA
b. President of NZSA
c. President of ACS
d. President of AMT
e. An AAS representative
f. STEMS Advisor to the Chief Scientist
g. CEO of AMSI
i. Chair of Planning Committee

Their tasks will include provision of oversight and strategic direction, monitoring progress and financial probity of the work of the Planning Committee, providing assistance in identifying possible sources of funding and securing funding, reporting progress to their respective organisations, and providing appropriate external representation of the work of the Planning Committee. This high level committee will also have a strong responsibility for advocacy.

Appendix 1. Bios and abstracts for invited speakers

Xiao-Li Meng

Professor Xiao-Li Meng is Dean of the Graduate School of Arts and Sciences and a distinguished Professor of Statistics at Harvard University. He is well known for the depth and breadth of his research and his innovation and passion in pedagogy, as well as for his engaging and entertaining style as a speaker and writer. Meng has received numerous awards and honors for the more than 150 publications he has authored in at least a dozen theoretical and methodological areas, as well as in areas of pedagogy and professional development. His interests include the theoretical foundations of statistical, statistical methods and computation, and applications in natural, social, and medical sciences and engineering.

Statistical Education and Educating Statisticians: Producing wine connoisseurs and master winemakers.
The distinction between statistical education and educating statisticians is of particular importance at the pre-graduate school level. In the past decade or so, we have taken a broader view of statistical education for Harvard's undergraduates, by shifting the focus from preparing a few to pursue Ph.D. in statistics to helping many gain a basic appreciation of statistical argument and insight, as a part of their liberal arts critical thinking training and experience. Intriguingly, the journey, guided by the philosophy that one can become a wine connoisseur without ever knowing how to make wine, apparently has led us to produce many more future winemakers than when we focused only on producing a vintage. At the Ph.D. level, our focus has always been to produce the best winemakers, to take the wine analogy further, but true expert winemakers need to master far more than merely the chemical process of fermenting juice into alcohol. We therefore introduced a Professional Development Curriculum (PDC) parallel to the usual course curriculum, starting from "Stat 303: The Art and Practice of Teaching Statistics," a required one-year course for all entering Ph.D.s, aiming at both producing well trained teaching fellows for undergraduate courses and effective statistical communicators in general. This talk shares a number of stories from our intoxicating journey and experiments, including a Riesling randomized trial conducted for "Stat 105: Real-Life Statistics: Your Chance for Happiness (or Misery)" to assess the single most influential factor in students' ability to judge wine quality (once they are over 21).

[Related articles are in Publications on Pedagogy, Professional Development, and Profession Building and Outreach (articles 0.5-0.11) at http://www.stat.harvard.edu/Faculty_Content/Meng-cv.pdf or by emailing meng@stat.harvard.edu]

Roslyn Prinsley and Alan Finkel

Dr Finkel commenced as Australia's Chief Scientist on 25 January 2016. He has an extensive science background as an entrepreneur, engineer, neuroscientist and educator. Prior to becoming Chief Scientist, he was the Chancellor of Monash University and President of the Australian Academy of Technology and Engineering (ATSE).

Dr Finkel was awarded his PhD in electrical engineering from Monash University and worked as a postdoctoral research fellow in neuroscience at the Australian National University. In 1983 he founded Axon Instruments, a California-based, ASX-listed company that made precision scientific instruments used at pharmaceutical companies and universities for the discovery of new medicines; after Axon was sold in 2004, he became a director of the acquiring company, NASDAQ-listed Molecular Devices.

In 2006, he returned to Australia and undertook a wide range of activities. He led the amalgamation that formed the Florey Neuroscience Institutes; he became Chair of the Australian Centre of Excellence for All-Sky Astrophysics (CAASTRO) and was a director of the ASX-listed diagnostics company Cogstate Limited. He was Executive Chair of the educational software company Stile Education, Chair of Manhattan Investment Group, Chief Technology Officer of Better Place Australia and Chair of Speedpanel Australia.

Committed to science education, Dr Finkel co-founded Cosmos Magazine, which in addition to magazine publishing operates a secondary schools science education program. At ATSE, he led the development and implementation of

the STELR program for secondary school science, which has been adopted in nearly 500 Australian schools. Dr Finkel also established the Australian Course in Advanced Neuroscience to train early career neuroscientists and is patron of the Australian Science Media Centre.

Dr Roslyn Prinsley is the National Adviser for Science and Mathematics Education and Industry in the Office of the Chief Scientist. In this role, Roslyn advises the Chief Scientist on the role of science, technology, engineering, mathematics across education and industry. She is Chair of the Office's Industry Working Group and Women in STEM National Committee. She has previously held senior positions in a number of organisations, including Sinclair Knight Mertz, RIRDC and Bioenergy Australia and has chaired National Steering Committees for two national research and development plans – New and Emerging Industries and Bioenergy and Biofuels – under the auspices of the Primary Industries Ministerial Council, and initiated and established a new organisation – New Rural Industries Australia.

Statistics – A National Perspective

[No abstract available]

Hamish Treleaven

Mr Hamish Treleaven is a banker of 30 years' experience. Over his career he has led quantitative teams responsible for pricing and trading derivative products, measurement of bank liquidity and funding risk, and the calculation of economic and regulatory capital requirement across credit, market and operational risk. He is currently the Executive General Manager of Portfolio and Market Risk Management at the Commonwealth Bank of Australia.

Statistics Education: a Banker's Perspective.

We are in the age of Big Data and Data Analytics. Digitisation is driving innovation and change in the Financial Services industry at rapid pace. Surveys show that over the coming decade, upwards of 30% of today's jobs are likely to be replaced by those requiring a more analytical or technology driven skill set. What does this mean in practice in the Financial Services industry? What are the keys to success, for those with a statistical or analytical education, in the commercial world?

Helen Owens

Ms Helen Owen joined the Department of Prime Minister and Cabinet as the Principal Advisor for Public Data Policy on 22 October 2015. Prior to this appointment she was the Assistant Secretary Data Policy in the Department of Communications and previously the General Manager of the Office of Spatial Policy in the Department of Industry. Helen is currently responsible for providing whole of government policy advice on the Australian Government's public data strategy, data infrastructure, data in the economy, and digital government.

A government / public data perspective

Government entities are increasing their digital service delivery. The volume of data entities collect and publish is also increasing. Given this, it is vital that the Australian Public Service has the skills, knowledge and capability to enable data-driven approaches to government policies, programmes and service delivery. Australia's prosperity will be significantly enhanced if the public service is able to effectively use data to tackle future domestic and global challenges as it advances through the 21st century.

The Public Data Branch in the Department of the Prime Minister and Cabinet has been leading delivery on outcomes from the Australian Public Service Public Sector Data Management Report released in December 2015. Among these is a Data Skills and Capability Framework to improve the capability of the public service to respond to new challenges using data analytics approaches.

Robert Randall

Mr Robert Randall is Chief Executive Officer of the Australian Curriculum, Assessment and Reporting Authority (ACARA). He brings to this role significant experience and success in curriculum, assessment and reporting projects, gained at both state and national levels.

Robert began his career as a teacher of mathematics in Perth before holding a range of positions within and beyond schools in Western Australia. In 1996 Robert was appointed Director, Curriculum, with the NSW Board of Studies, and in 2001 took up the position of Director of Curriculum K–12 with the NSW Department of Education and Training. He started working with ACARA in 2009.

Critical issues to be addressed to transform statistics education– a school curriculum perspective.

In 2012, with the advent of the senior secondary Australian Curriculum, opportunities for students to study statistics improved on previous opportunities. Rob's presentation will provide a recount of these developments and an assessment of what further work might be done to sustain and improve opportunities to improve statistics education.

Louise Ryan

Professor Louise Ryan is Distinguished Professor of Statistics at University of Technology Sydney. After leaving Australia in 1979 to pursue her doctoral training in Statistics, she spent 25 years in the Department of Biostatistics at the Harvard School of Public Health, eventually serving as the Henry Pickering Walcott Professor and Chair of the Department. In 2009, Louise returned home to Australia to take up a position as Chief of Mathematical and Information Sciences at CSIRO. She joined UTS in 2012. Louise is well known for her contributions to statistical methods for environmental and health research.

Statistics Education: an Academic's Perspective.

Our world is becoming increasingly connected, digitised and data rich, with ever expanding capacity to draw on and link data from multiple sources, in multiple formats and for multiple purposes. Drawing on 30 years as an academic statistician, mostly in the United States, but for the last seven years in Australia, I will talk about how these developments are changing the way statisticians need to engage with data, along with associated challenges and opportunities. I argue that unless our training evolves to embrace a stronger emphasis on computer science, our discipline risks being left behind. Softer skills, such as communication, project management and collaboration are also really important in the modern age. We need to find ways to provide our students with such training, whilst at the same time providing them with the rigorous foundation that underlies sound statistical thinking. I will briefly talk about some relevant initiatives from the ARC Centre of Excellence in Mathematical and Statistical Frontiers (ACEMS).

Nicholas Fisher

Dr Nicholas Fisher is Visiting Professor of Statistics at the University of Sydney and Principal of ValueMetrics Australia, an R&D consultancy specialising in Performance Measurement. His research interests include methods for data measured as directions, statistical graphics, performance measurement, and applications in the Earth Sciences and Quality Management. As a former President of the Statistical Society of Australia, he has been actively involved in professional accreditation of statisticians, statistics education, and enhancing public awareness of the importance of Statistics and of statisticians. He chaired an ABS/SSA team that worked with ACARA on statistical aspects of the Mathematics curriculum.

Statistics Education in Australia: *We need a revolution*.

Statistics education in Australia requires a disruptive transformation to have any chance of coping with the current and emerging requirements of the Australian workforce, and we need to set about this transformation now. As things stand, we are facing a massive shortfall of all levels of graduates in Statistics that is an order of magnitude greater than current rates of graduation.

Statistics, unlike Mathematics, is intrinsically concerned with learning from data, and the data come from elsewhere – from Science, Medicine, Engineering, Transportation, Politics, … the list is almost endless. So, statisticians need to be working with people from these disciplines on their problems. And they need a broad range of skills and knowledge to do this properly, of which the ability to manipulate formulae is just one of many. And as data become more ubiquitous and more plentiful, the skill set that is required keeps changing.

What, then, needs to be done? Four obvious critical steps are to:

1. Design learning programs at school and university that equip students with appropriate skills, knowledge and knowhow.
2. Find a way to teach Statistics that both provides an appropriate learning environment and can cope with the massive increase required in the number of graduates.
3. Create learning programs for school teachers who are not Statistics graduates to allow them to teach Statistics at schools. (If you're currently a Maths teacher with no background in Science, what sort of program would you need to equip you to teach Year 12 Physics, Chemistry, Biology or Economics?)
4. Develop and implement a marketing plan to attract students and teachers to Statistics.

Appendix 2. Summaries of presentations by invited speakers

Xiao-Li Meng

1. An important distinction between "Statistical education" and "educating statisticians". Many academic departments focus on the latter to the detriment of the former. This is a mistake. By focussing effort on broader statistical education, we not only get a better appreciation about the field as a whole, but we may identify some potential talented statisticians in the process. Xiao-Li used an analogy of wine connoisseurs/wine lovers versus master wine makers – without the connoisseurs and wine lovers, there would be no market for master wine makers either!
2. To do a great job with broader statistical education, we must be responsive to modern trends (larger, deeper, faster). We must balance core development with applications and interdisciplinary research because it is generally the latter that most audiences will be interested in. Finally it is important to put the right infrastructure and teacher training in place.
3. At present, the discipline is in an enviable state where enrolments in introductory statistics courses as well as interest in concentrating in statistics is increasing. He showed a graph illustrating exponential growth over the past 10 years at Harvard College in statistics concentrators. Of course, this is a general trend as well.
4. Importance of "Dream Team with Team Dream" and of attracting and retaining outstanding teachers. Also important to enhance the pedagogical culture via training programs for teaching fellows. Xiao-Li teaches a course called "the Art and Practice of Teaching Statistics" which is required for all students enrolled in the PhD program.
5. In terms of the actual teaching, it is important to resist the instinct to start with the mathematical foundation. Focus instead on more applied ideas that will grab the interest of a broader group of students. The key is to more to motivate the students to learn more statistics, rather than to teach them a specific body of material. Xiao-Li taught a very non-conventional course that was organized around practical exploration and experimentation (via wine and chocolate tasting!). Students become motivated through the experience to think about things such as good experimental design *etc*.

Roslyn Prinsley

1. There is considerable fragmentation of effort. A lot of small-scale activity is occurring, with people scrambling to keep up. The result is an unsustaining, underperforming and inequitable Mathematics (including Statistics) education system.
2. Consequent message: if we want to change the way Statistics is taught and to attract more children to study it, we need to combine our efforts with those of the education system,

Mathematics education practitioners, and those working on the evidence base for best practice teaching and professional development in Mathematics and Statistics.

3. Supply falls a long way short of demand, here and overseas, and the gap is increasing, in spite of all the evidence of the growing importance of professional statistical skills in many sectors of the economy. Further, many people are entering Statistics from other areas, without formal statistical training.
4. Statistical skills are important for all scientists, in all phases of scientific experimentation. We not only statisticians, we need scientists who can think like statisticians.
5. We need to excite students about Statistics well before Years 11 and 12. 'Liking' a subject is important for participation and success, and *vice versa*. Achieving this is not easy. 20% of people teaching Mathematics at secondary school are teaching "out of field" (the percentage is much higher at primary school). Most teachers have had at most one Statistics course as part of their university studies, and many generalists have had none.
6. Compared with overseas, Australia is declining in terms of performance of students in international tests. That said, a 2015 study found evidence that performance can improve quite quickly (*e.g.* within 2 years) when a school adopts 'best practices' in teaching. This needs the clear commitment of the Principal of the school.
7. Consequent message: we need to familiarise ourselves with the best practice activities currently underway in Australia and overseas (New Zealand, Singapore, USA, …). The Office of the Chief Scientist can help with this.
8. More generally, we need a plan that all governments, educational institutions and the private sector can sign on to. It requires three priorities:
    a) A coordinated approach to building a strong evidence base of best practice teaching so that we can build on those success stories in a captivating and meaningful way.
    b) Using this evidence base, we need universities to train teachers and then schools to support them with professional development and engaging resources.
    c) We need to expect high standards in teaching Statistics, so need to educate Principals to be leaders in Science and Mathematics.

Hamish Treleaven

1. The skill sets of statisticians are in very high demand and drive the innovation agenda.
2. There are two major sets of roles that have emerged recently in the world of Finance: that of the Chief Data Scientist (CDS) and the Data Scientist (DS); and the Chief Data Officer (CDO) and the Data Officer (DO).
3. The background to the CDS/DS role is the increasing emphasis on ease of customer access to products, and speed with which decisions relating to customers need to be made. These lead to the need to be able to model the customer experience, and a spectrum of types of Risk, which is work grounded in Statistics. Because this is happening throughout a person's

lifetime, lifetime analysis is becoming increasingly important. The advent of robo advice and blockchain transactions are putting pressure on computational capability, which is why quantum computing is of increasing interest. Similarly, algorithms to improve cyber security and for preventative and detective controls are all heavily Statistics-based. The role of the CDS/DS has emerged to focus on this area.

4. The CDO/DO roles relate to developing data management strategies; frameworks for managing data; understanding and describing what good data management looks like; agreed definitions, quality standards and storage and back-up approaches; and ways of handling data destruction. Many companies don't do these things well, and need to reinvent their architecture, systems and processes to meet the needs of the digital age.
5. There are two keys to success for people with Statistics qualifications seeking to make a career in the world of business – **effective communication skills** and **commercial acumen** – and the time to start acquiring them is at university.
6. Effective communication skills:
   a) Be clear and concise, leaving the audience in no doubt about what's in it for them
   b) Avoid jargon, technical terms and acronyms.
   c) Get to the point quickly – senior people are smart, and time poor.

   The Australian Institute of Company Directors runs courses on how to write papers for boards, which are also relevant for writing for senior executives.
7. Commercial acumen:
   a) Understand the industry you're in.
   b) Understand the drivers of profitability.
   c) Know who your customers are and why.
   d) Know what your competitors are up to.
   e) Understand the economic environment and its impact.
   f) Know about important regulatory factors – both for your company and for your competitors (for which these factors may be different, *e.g.* if they are overseas).

Helen Owens

1. The explosion in data volumes will also mean there will be new job descriptions and roles emerging. CSIRO's Data61 report *Tomorrow's Digitally Enabled Workforce* examines trends and scenarios for jobs and employment markets in Australia over the coming twenty years. Two of the six new future job growth areas identified in the report are specifically driven by the growth in data:
   a) Greater specialisation by big data analysts – will need statisticians and data specialists who have skills in machine learning, automation, cyber security, encryption and distributed (cloud based) systems.
   b) Complex decision support analysts – as decision makers in the future are armed with more data and information, the decisions they make with that data are likely to hold

larger consequences for stakeholders and societies. Complex decision support analysts will analyse and interpret large amounts of data to identify options and make operational and strategic decisions.

While these jobs are just two of the predicted future growth areas, as governments and companies turn to vast quantities of data in search of useful information, Australia's capacity to remain competitive in the digital economy will be contingent upon its ability to use and harness the value of data.

2. A 2013 survey [commissioned by Listpoint in the UK] of public sector staff in the UK found that 72% of respondents agreed that it is becoming increasingly important for all public servants to know how to access, share and use data, but 57% did not know how to access and interpret the datasets. 75% did not know what data was available outside their department to help develop new approaches to service delivery or policy development. Many other public or civil services around the world have also identified the importance of their policy and program makers having data skills and capabilities to solve problems and develop new policies.
3. The UK Government is building the data analytics capabilities of its public sector staff through four strategies:
   a) building the right environment by replicating private sector culture;
   b) getting the right people in by hiring high-profile experts from the technology and private sectors, with the expectation that they would 'bring in' other experts;
   c) embedding policy staff alongside the makers and the 'doers' in dream teams of policy officers, data analysts and visualisation experts; and
   d) making bureaucrats accountable for progress through a Minister-chaired Board which provides Ministers with means to assess and direct the civil service as it progresses through the digital transformation agenda.
4. The UK has implemented specific initiatives to "help government agencies and departments transform themselves into intelligent consumers of their own data" such as:
   a) Setting up a cross-government Data Science Accelerator Programme, to train data analysts in cutting-edge tools and techniques.
   b) Recognising the transformational power of data by setting up a program of lunch-time code clubs to develop opportunities to get stuck into data.
   c) Civil Servants across central and local governments have also been given free data training vouchers to sign up for data courses at the Open Data Institute and the Open Knowledge Foundation.
5. PM & C commissioned a report (*Public Sector Data Management Report*, December 2015) to deliver a roadmap to unlock the potential of public service data to drive innovation, efficiency, productivity and economic growth. Recommendation 5 from the Report

recommends a whole of government approach to building data use and analytics capability within the Australian Public Service. In response, the *Deputy Secretaries Data Group*, agreed to a Data Skills and Capability in the APS Framework, to empower the Australian Public Service to harness the value of data and aim to increase data literacy across all levels of the APS. The Framework comprises of four key components:

a) Data Fellowships to provide advanced data training to high performing data specialists in the APS.
b) APS officers will undertake three month placements to tackle a data-related problem from their organisation
c) Leveraging partner organisations' in-house training and expertise through Data Training Partnerships.
d) Universities are increasingly offering data specialty courses.

The Australian Public Service Commission is coordinating an *APS Data Literacy programme* to provide a suite of initiatives to improve the data capabilities of non-specialist APS officers.

Robert Randall

1. National curriculum: Foundation – Year 10. Being implemented around the country. It contains more Statistics and Probability than was previously in State curricula, the amount being taught is greater than in other countries, and every student is being taught some Statistics. The challenge is: how to continue to improve?
2. National curriculum: Years 11 and 12. There are four courses, Essential, General, Methods and Specialist. The challenge is: how to make the content accessible and relevant. The extent of adoption around the country is variable. However, there is definitely more Statistics in the national and State & territory Curricula than there was before.
3. However, how to go further with the Years 11& 12 curricula, to get a good return on investment for all the time, energy and resources that went into its development?
   a) Stabilise for a few years – perhaps 5?
   b) Monitoring is under way to get feedback on the currency of the material. 5 years may be too long in some areas. Quality of the curriculum – need to benchmark internationally. Does the curriculum help teachers to do a better job, to make a difference? Assessment will play an important role here. How should it be done?
4. Further specialisation of courses. This pathway may NOT deliver the outcomes we are seeking at schools – need to check with Barry McGaw about what prevents good uptake by students.

Louise Ryan

1. Louise talked about one of her statistical heroes, the late Professor John Tukey, who had the right blend of theory, methods and application and who enjoyed solving real problems and getting his hands dirty with data.
2. Having lots of statisticians involved in the "virtuous cycle of collaboration" is key to growing and maintaining a world capability in statistical science. The VCC starts with getting engaged in real world problem solving, having the time to follow-up on the ideas for new and better theory and methods, then bringing those new methods back to the real world problem. The US has a strong culture of collaboration that has really helped the statistical sciences thrive, especially in the health and medical environments. Unfortunately the same cannot be said for Australia.
3. Some of the problems with the Australian environment include
    a) Statistical Science is in a period of disruptive innovation – responding and evolving in response is difficult, especially in Australia where most universities tend to lack critical mass. Lack of critical mass is indeed one of our biggest problems. Macquarie is one of the few standalone departments. In general, stats is usually bundled with maths. A huge problem is that stats is generally quite separated from computer science.
    b) ARC funding levels are flat or declining (in terms of number of grants awarded) in general and definitely declining in the statistics area.
    c) ARC funding model is largely skewed towards individual investigators and it is easy for collaborative and interdisciplinary work to fall in the cracks.
    d) Typical university model does not really help either. Hard to value interdisciplinary work, reward systems don't align, faculty silos create disincentives around collaboration
4. There are a number of effective things we can do, including:
    a) Foster and support effective shared teaching efforts such as the Biostatistics Collaboration of Australia.
    b) Push deans and heads of school to value interdisciplinary support
    c) Seek industry and other non-traditional sources of funding
    d) Lobby ARC to develop new funding models that more effectively support interdisciplinary work. There are some excellent models in the US and VicBiostat is a great example is Australia, unfortunately about to lose funding.

Nicholas Fisher

1. There is ample evidence that we have a crisis on our hands: the number of people emerging from universities with formal statistical qualifications is an order of magnitude smaller than what is needed to meet current and future workforce needs. And this is not a

uniquely Australian problem: for example, the same holds true in the United States, where the numbers of Bachelor, Master and PhD graduates are at least trending positively but still fall woefully short of what is needed.

2. Responding to this crisis by incremental improvements simply won't work: we need a disruptive transformation to have any chance of coping with the current and emerging requirements of the Australian workforce, and we need to set about this transformation now.
3. Statistics, unlike Mathematics, is intrinsically concerned with learning from data, and the data come from elsewhere – from Science, Medicine, Engineering, Transportation, Politics, … the list is almost endless. So, statisticians need to be working with people from these disciplines on their problems. And they need a broad range of skills and knowledge to do this properly, of which the ability to manipulate formulae is just one of many. Further, as data become more ubiquitous and more plentiful, the skill set that is required keeps changing.
4. What, then, needs to be done? Four obvious critical steps are to:
    a) Design learning programs at school and university that equip students with appropriate skills, knowledge and knowhow.
    b) Find a way to teach Statistics that both provides an appropriate learning environment and can cope with the massive increase required in the number of graduates.
    c) Create learning programs for school teachers who are not Statistics graduates to allow them to teach Statistics at schools. (If you're currently a Maths teacher with no background in Science, what sort of program would you need to equip you to teach Year 12 Physics, Chemistry, Biology or Economics?)
    d) Develop and implement a marketing plan to attract students and teachers to Statistics.

Appendix 3. Summaries of comments by panellists

Anna Wethereld

1. Need to nurture talent. What is the desired Customer Experience? What are the ways that we get students to stay with Mathematics (and Statistics) until year 12 and then continue at university.
2. The introduction of Statistics into Years 11 and 12 means that teachers will need substantial support not only to teach students well but to imbue them with a passion for the subject. So good support materials will be critical and will need to capture the vibrancy needed to achieve this. If we recruit teachers from other areas to teach Statistics, they will need to be equipped with the appropriate skills to teach well.
3. Emphasize an interdisciplinary approach highlighting opportunities to demonstrate the widespread applicability of M & S.
4. How to assess statistical literacy?
5. Design of curriculum should be infused with the use of technology.
6. Emphasize to students the transformational use of data, and make corresponding transformational use to of data improve outcomes.

Geoff Prince

1. Remarks relate to the Decadal Plan (DP); see https://www.science.org.au/support/analysis/decadal-plans-science/decadal-plan-mathematical-sciences-australia-2016-2025 and supporting documents.
2. DP has a recommendation relating to need for effective teaching of M&S in disciplines other than M&S. A high level of statistical literacy is needed among STEM graduates, business graduates and others. It will involve our proactive engagement with the other disciplines. This is currently not universally the case at present, when approaches are made by other disciplines to collaborate. Our leadership must do better.
3. In preparing graduates, M&S currently mostly taking place within framework of a Science degree program. However, these programs tend to be dinosaurs compared, for example, with Engineering programs and their emphasis on project work. We have a long way to go in making our graduates 'fit for purpose' when they seek jobs.
4. Can still take a Mathematics major without taking any Statistics. This should not be possible: Math graduates should be able to deal competently with data, and Stats majors should learn significant mathematics. In particular, many graduates going on to teach Mathematics at schools have not learnt any Statistics. So, our undergraduate programs need major overhaul. The two professional societies should collaborate on accreditation of degree programs to ensure that these twin problems are resolved.

5. When designing 'out-of-field' program to help teachers become Mathematics teachers, they also need just as much Statistics knowledge.
6. An AMSI discussion with industry leaders identified coding as an important capability of graduates, and ability to handle data as essential.

Jacqui Ramagge

1. Australia has a massive problem in Informatics – Mathematics, Statistics and Computing –in terms of the demand from industry versus the supply, and of these, the deficit in Statistics is the most acute. Yet they are the foundation of Australia's future prosperity so we do ourselves a great injustice to ignore the problem.
2. Industry is starting to notice that there is a problem. However, by the time they are fully awake, the educational system will have imploded, because the demand for graduates from industry has been so great that the teaching profession has been starved of personnel.
3. Visibility is a big issue: few job advertisements call specifically for a 'mathematician' or a 'statistician', and even when we're in this job, it is not evident that M/S is what we are doing. Big need to enhance visibility – *which needs effort not just from us but also from industry*! And nothing speaks louder than money: industry needs to speak much more loudly and to put its money where its mouth is, *e.g.* via scholarships targeting people in Informatics, … .
4. Strongly approve of the APS re-training initiative … but why didn't JR (as a Head of School) know about it? And what is industry doing in this regard and how is it being promoted and publicised? How about seconding staff to universities to do PhDs in Statistics?
5. False dichotomy between research excellence and teaching excellence at universities: people think it's either one or the other. It's not: can be excellent at both (*e.g.* Harvard – cf. X-L M's presentation). Need to move outside the system to get appropriate income to support both.
6. Need a culture that supports teaching excellence at all levels. Need a cultural revolution, moving from a culture of talent to a culture of (hard) work. Need to move away from self-deprecating and belittling behaviour towards our disciplines.
7. In Spain, it is EXPECTED that everyone does Mathematics. This is so deeply ingrained that there are common insults that depend on mathematical knowledge to interpret.

Jose Martinez

1. Since 2004, exponential growth in need for Statistics (the language of measurement), probably deriving from the steady transfer of Big Data skills, knowledge and knowhow from researchers through the large corporations such as banks, and on to smaller corporations and groups (*e.g*. Loyalty Programs). And capability with Statistics – the ability to

understand a problem, formulate a statistical approach, come up with a result, and have the skill to translate it for people – leads to interesting and challenging and lucrative jobs.
2. Need to be able to communicate the limitations of big data to senior officers: can't solve everything, and when a solution is available, it must have error bars … getting which can take a lot more effort.
3. Statistics is the Swiss-army knife of disciplines.

Murray Cameron

1. People do not understand the purpose of models. An understanding of the role of models of real-world situation– their formulation, how they are tested using prediction based on small amounts of data, and subsequent evaluation of outcomes … basically, how knowledge develops – is crucial to tackling the big problems the world faces. So we need more data analysis connoisseurs. We have mechanisms to address this problem (*e.g*. *Significance*, *The Conversation*, …), but we need more. This means we need not only to market to children but also to their parents to heighten their awareness.
2. The future will be good for data scientists and analytics, but statisticians may be missing the boat. There is a big market there for us, but do we realise it? What to do here?
3. Need to think about the spectrum of possible jobs for PhDs. Many more PhDs trained than are needed in academe. How does the training need to change to develop much better uptake by industry, and how can industry learn about the value to them of employing suitably trained PhDs? Programs of industry doctorates need to develop capabilities appropriate to industrial jobs.

John Henstridge

1. There are masses of problems in industry that require the hand / the eye of a statistician to be solved; of all the mathematical sciences, it is Statistics that is the most readily applicable. Why aren't there sufficient numbers of statisticians to address these problems?
    a. Massive deficit of understanding by people in industry of what they need.
    b. Statistics is almost universally badly taught.
    c. As an employer, desperately short of eligible applicants for jobs. The critical need to effect a large increase in the numbers of Statistics graduates is not an issue currently recognised by universities. Teacher quality is a bit issue in this regard, as is the need to make Statistics relevant and fun.
2. It's a marketing / branding problem as well. Need to develop a clear view of what we are and be consistent about it. The SSA Professional Accreditation program is important in this regard.

Peter Howley

1. Why haven't we got a Statistics version of CS+X? Need to tap into existing models and build on them?
2. Context is critical when teaching Statistics, together with the concept of statistical investigation (as appropriate to the level of the student), and the key aspect which distinguishes Statistics from the deterministic nature of Maths, namely understanding and accounting for variability.
3. Measurement is very relevant to each individual's life, but do they recognise it? We say Statistics is omnipresent, cross-disciplinary, fundamental to all fields, but do we demonstrate it, do students feel it, do they engage in and live it? Do we do it in a manner than wins over those with not always positive perceptions, do we create a grape vine of people spreading the word for us? Generally not, we must be better at doing so.
4. Need two streams to be supported – the mathematically oriented students and the less mathematically oriented.
5. Need to engage industry both at university and at schools. There are some initiatives that need to be brought together and built on. We must engage industry, as our (teachers of Statistics) words are much stronger coming out of the mouths of those in industry.
6. Teachers need our support – resources, professional development, … - this cannot be undertaken at arm's length, there must be a collaborative and supportive approach.
7. How will people be recognised for their contribution towards improving Statistics education?
8. There is a need for a cultural change in the manner in which Statistics Education is espoused and supported (not left to 'statistical education' people – need for all to engage; more active involvement and engagement with industry and interdisciplinary endeavours – be seen, be visible, but tactfully so).

Appendix 4. Reports from the Working Groups

STEMS-2016 Working Group on Schools (Primary and Secondary) Statistics Education

Background:
The participants in this working group comprised academics from Australian and New Zealand universities, teachers from secondary schools, as well as industry and national organisation representatives, including the CEO of AAMT. A list of attendees is provided at the end of this report.

Discussion focussed on establishing principles surrounding the teaching of statistics in schools, which assist in of increasing students' connection, understanding of, and affinity with Statistics.

Summary:
The following fundamental recommendations emerged:

1. Teach statistics as it is practised: replace calculation-focus with contextual and inspirational project based learning, engaging technology and computers
2. Statistics must establish its own identity
   i. Ensure it is recognised by students as a valuable and accessible profession and career;
   ii. Year 11/12 Statistics to be taught as a stand-alone cross-disciplinary subject rather than as an element of Mathematics.

These recommendations point to the need for systemic and systematic collaboration between tertiary and industry personnel and schools, in developing mechanisms which support teachers towards achieving the desired outcomes.

Funding, including sponsorships, grants and linkage projects, and building upon existing successful initiatives in statistics education, would seem to be critical avenues to pursue to support timely implementation and success in sustaining these recommendations.

Recommendations, Challenges and Actions required and in train.

1. **Teach statistics as it is practised: replace calculation-focus with contextual and inspirational project-based learning, engaging technology and computers**

   Echoing comments from former Chief Scientist, Ian Chubb, surrounding the teaching of the sciences, the discipline of statistics must be taught as a lively, context-based, interdisciplinary and investigation-oriented endeavour, like it is practised:
   - students to initiate, participate and undertake investigations emulating and connected with real practice;
   - utilise context and students' interests as points of motivation;
   - statistical literacy to be addressed as a minimum;
   - ensure the key role that computers play in the practice of statistics, along with the value they can provide as a pedagogical and motivating tool, is utilised.

Challenges:

a. Teachers generally are relatively inexperienced in the field of Statistics and how it is practised. School teachers' inexperience in the statistics profession is a significant hurdle to inspiring student interest.
b. Teachers have many competing interests and demands upon their time.
c. Tertiary teaching programs provide pre-service teachers relatively low, or no, exposure to, or education in, Statistics.
d. Equity issues surrounding schools' access to technology.

Actions required:

a. Establish teacher support mechanisms, including but not limited to:
    - professional development (PD) activities,
    - national, state and regional champions – working in conjunction with existing successes/initiatives

    Tertiary, with industry support, must take the lead and work with schools and teachers along with national and state teacher organisations and boards of study to upskill, advise and guide. This shouldn't be attempted at arm's length. Strong collaborative links between schools, tertiary and industry must be built and sustained.

    Passionate tertiary leaders in statistics education must be supported to engage with and support schools to ensure continuity and sustainability. Teachers with such skills should also become champions– potentially supported by fellowships.

    Schools, higher education and industry must align and unite to address internationally-recognised issues.

    Focus not only on training maths teachers to teach statistics, but also those in other fields.

    Identify successes (exemplars/best practice) within and external to statistics – benchmark internationally. Link to current/popular topics and practices and meaningful context.

    Explore potential to engage school teachers via the tertiary system's AGR network to participate in PD activity within system-wide/national training:

    - teachers attend AGR at their local University, facilitating both increased connections between tertiary and schools, and enabling the expertise of multiple speakers nationally to be utilised across several sites simultaneously (spreads workload, taps into breadth of expertise, enables cross-fertilisation of ideas between teachers).
    - create modules for teaching: benchmark internationally and nationally.
    - Become familiar with state and national curricula requirements:
        - Identify commonalities
        - Discuss with teacher groups to identify what they need
        - Explore existing materials to vet and use
        - Identify needed additional materials

b. Develop a stronger focus on Statistics within pre-service teacher programs (to develop not only existing teachers but those in training), through increased exposure to statistics within undergraduate BTeach programs: not only Maths Education students, but also those focussing on the Sciences, Physical Education, etc
c. Support teacher and school engagement in project-based learning techniques surrounding statistical investigation cycle:
    - Utilise and integrate National Schools Poster Competition within curriculum: develop resources to increase engagement
    - Connect with national curriculum 'general capabilities' and 'descriptors'. It was noted that these, more so than the curriculum's syllabus outcomes, very closely align with the approach we wish to see applied (statistical investigations, displays, etc). Such descriptors exist in many programs, not only mathematics.
d. Clarify impediments to technology access, i.e., access to computers/devices, or costs associated with software, or other.
e. Consider introducing iNZight or similar free online software to make statistical analyses and interpretation more accessible.
f. Consider iSTEM-type approach to teaching statistics - develop project-based learning modules, with connections to interdisciplinary subject area: see p.24 of document at http://meprogram.com.au/wp-content/uploads/2016/02/iSTEM-Board-of-Studies-Course-Outline-08_04_16.pdf
g. Tap into the industry and practising statisticians' expertise: connect such practitioners with schools as exemplars

Actions in train:

a. AAMT and SSA collaborating: CEO of AAMT and Statistics Education Chair of SSA are developing a position paper surrounding Statistics
b. Online resources to support teacher and student comprehension of statistical techniques as well as statistical investigations via the National Schools Poster Competition https://www.ssaipostercomp.info/ are being developed, likely completed by February 2017 (http://statstuneup.com.au/ complementing similar mathematics materials available at (http://mathstuneup.com.au/).
c. Module with NSW BOSTES-endorsed Stage 5 iSTEM course exists and supporting materials are being considered.

2. Statistics must establish its own identity

i. Ensure it is recognised by students as a valuable and accessible profession and career
ii. Year 11/12 Statistics to be taught as a stand-alone cross-disciplinary subject rather than as an element of Mathematics

To the first sub-point:

This point speaks to the very core of establishing statistics as a recognised and viable career option; one which is clearly visible in students' minds and connects with and/or supports their interests and passions.

To the second sub-point:

Statistics needs to establish its own identity, one that is not entirely dependent upon mathematical skills, nor seen as simply a subset of mathematics. Doing so would help establish itself as truly interdisciplinary, more widely accessible and tapping into the skills of the many non-mathematics teachers who may be able to deliver/co-deliver such a course, as well as encouraging those students less enchanted by mathematics but able to engage with Statistics.

In the interim, or in any event, the teaching of statistics (within mathematics) must connect with the many other subjects, engaging teachers outside mathematics to work with the maths teachers delivering the core material and help provide contexts and applications.

Challenges (for both sub-points):

a. As per those noted with Recommendation 1. Additionally:
b. Teachers and career advisors are not familiar with the extent of the role of the practising statistician nor the variety of career opportunities available.

Actions required

a. As per those noted with Recommendation 1. Additionally:
b. Benchmark against international methods/successes in Statistics and other disciplines
c. Develop the STATS+X initiative, where X is the individual's passion or area of principle interest (medicine, social sciences, etc), and link with the need for statistics and associated statistical investigation or exploration, advertising the interdisciplinary nature of statistics and the potential enjoyment therein.
d. Engage champions and experts in shameless promotion of statistics:
    - by industry representatives
    - by practising statisticians
    - by tertiary educators
    - by enthusiastic and believable representatives (appealing statistics advocates)

    Champions to:
    - Attend schools
    - Attend and **present at interdisciplinary conferences** and clearly identify the role of, need for and value of statistics within that field
    - Publish accessible materials that are lively and enlightening and engaging (develop 'must see' reading and information)
    - Ensure a grape vine is created where statisticians no longer are required to sell themselves, where statistics is recognised as 'the Swiss Army Knife of disciplines'; and is accessible/achievable as a career.
    - Ensure interdisciplinary connections are established, clear and maintained
    - Ensure the websites like the following are developed and disseminated
        - http://garthtarr.com/jobs-for-statisticians/
        - http://www.amstat.org/careers/whatdostatisticiansdo.cfm

As a starting point:

- Utilise existing industry-tertiary relationships
- Utilise SSA members who are practising or have experience
- Work with CSIRO's SMiS program, and other outreach programs (Choose Maths, etc) who currently attend schools and identify how this may be integrated with their programs

Identify industries where statisticians are employed and convince to take active role.

Actions in train:

a. AAMT and SSA collaborating: CEO of AAMT and Statistics Education Chair of SSA are developing a position paper surrounding Statistics.
b. Online resources to support teacher and student comprehension of the role of statistics and careers are being developed, expected completion February 2017, and available at http://statstuneup.com.au/ and https://www.ssaipostercomp.info/.
c. Module with NSW BOSTES-endorsed Stage 5 iSTEM course exists and supporting materials need to be developed to assist implementation by teachers.
d. Developing industry experts videos for schools – short excerpts of engaging and enthusiastic interdisciplinary professionals promoting the activity surrounding Statistics and its importance in practice: expected completion February 2017, and to be available at http://statstuneup.com.au/ and https://www.ssaipostercomp.info/.

   See example at https://www.ssaipostercomp.info/videos.html#turner – helping to open up STEM Festival at ACT school, informing about the role of, and opportunities within, the field of Statistics.
e. Publications in Science and Math Teacher Associations journals/magazines

Working Group to carry Schools initiative forward

- Greg Murdoch (Teacher)
- Kevin Trimble (Teacher)
- Susan James (AMSI)
- Michael Stewart (NSW SSA)
- Pip Arnold (New Zealand)
- Jose Martinez (Qantas)
- Peter Howley (SSA) – Chair
- (AAMT rep – Will Morony to advise)

Other supporters

- Jane Watson (UTas)
- Anthony Harradine (Teacher)
- Mary Coupland (UTS)
- James Baglin (RMIT)

The group proposed steering committee representatives, with which working parties would engage:

- SSA (Scott Sisson)
- AAMT (Will Morony)
- AMSI (Geoff Prince)
- Business Council of Australia
- AIG
- ACARA

Other supporters

- Jane Watson (UTas)
- Anthony Harradine (Teacher)
- Mary Coupland (UTS)
- James Baglin (RMIT)

List of attendees

- Caro Badcock (Shimsco Consulting)
- Minh Huynh (USyd)
- James Baglin (RMIT)
- Michael Stewart (USyd)
- Peter Howley (UON)
- Scott Scisson (UNSW)
- Greg Murdoch (teacher)
- Valerie Barker (teacher)
- Susan James (AMSI)
- Jose Martinez (Qantas)
- Jessie Roberts (PhD student, QUT) – one session
- Anthony Prasad (teacher, NSW)
- Noleine Fitzallen (UTas)
- Jane Watson (UTas)
- Pip Arnold (NZ)
- Anthony Harradine (teacher, SA)
- Will Morony (AAMT)
- Kevin Trimble (teacher)
- Chris Wild (Auckland University, NZ)

STEMS-2016 Working Group on Tertiary (undergraduate) Statistics Education

Background

The working group articulated two principles that should underlie any future recommendations for undergraduate training that includes statistics as a key component.

Principle 1:

The desirable skills/attributes of any statistics graduates need to include the capacity to frame, understand and solve real problems using data. The problems can arise within any domain, and domain context is critical to arriving at practical and useful solutions.

Principle 2:

University offerings in statistics need to be nuanced and diverse, to match the diversity of backgrounds and interests of the students we teach. Further, access to statistics courses needs to match the needs and abilities of students in the disciplinary cohorts that use statistics.

Recommendations on Curriculum

Recommendations for a first course in Statistics

- Begin with real problems from suitable domains, supported by authentic data with complexity typical to that domain (e.g. missing values in survey data, etc.). Examples of rich data repositories include the Australian Data Archive (www.ada.edu.au), however the use of specific domain data is strongly encouraged, including gathering of new data as opportunities arise. Both SSA and AMSI can play a prominent role in developing and maintaining interesting and diverse data archives. The development of intuitive interfaces so that data can be easily explored and downloaded is essential.
- Introduce and develop facility with software to allow rich visualisations of data (e.g. iNZight, free software built on top of R and developed at the University of Auckland, or commercial offerings such as Tableau) and modelling of data. Calculations of and algebraic representations of constructs such as sums of squares can be de-emphasised in favour of computer output.
- Learning outcomes should emphasise the kinds of problems students are expected to be able to handle (e.g. comparing groups in a medical experiment) rather than on the learning of specific techniques (e.g. one-way ANOVA) for their own sake – that is, methods need to be motivated by real data questions rather than the theory leading data "examples".
- While it is expected that a wide range of statistical techniques will be covered in order to meet disciplinary requirements, the focus of the course should be on applications rather than on techniques *per se.* Further, when techniques are introduced and discussed, their implementation in computer packages should be emphasised rather than pursuing a more theoretical, mathematical development.

- Second- and later-year courses in statistics should continue to require sufficient mathematics pre-requisites to support the development of statistical methodology with appropriate mathematical rigour, but also need to allow for developing statistical thinking independent of formal mathematical development of statistical methods.
- Critically, pre-requisites or co-requisite structures also need to include computer programming courses as computer science has emerged as a vital supporting discipline for the modern practice of statistics. Collaboration with Computer Science departments in this respect is critical.
- While the working group supports the recommendation in the Decadal Plan[4] to require at least intermediate Year 12 mathematics for entry into degree programs in Science, Engineering and Commerce, entry to introductory courses in Statistics should remain flexible, noting the value of Statistics to many disciplines outside STEM disciplines, including to the Arts and Humanities.

Recommendation: Creation and coordination of a first course convenors' group

- First course convenors/curriculum leaders from each university should be invited to meet annually as the *First course convenors group*. The brief of this group is to support the building of strong foundations courses in Statistics at tertiary institutions through information and idea sharing, as well as the sharing of teaching resources, including curricula, datasets, books and supporting materials, developed in concert with experts in other disciplines.
- The group should meet at least annually perhaps as part of a continuing annual STEMS conference.
- A working party of this group should coordinate to assemble exemplar materials as a precursor to developing a repository of data and examples for use in first courses in Statistics.
- The group should be supported (either financially or in-kind otherwise) by SSA, with additional support requested from AMSI and potentially from other sources such as the Office of the Chief Scientist, industry support, etc.
- The Statistical Society of Australia should house and maintain repositories for data and course materials (including, for example, assessments). These materials could formally be maintained through the Statistical Education Section and hosted via the SSA web site.

Increased need for cross-disciplinary approaches to degree structures

Recommendation: Statistics groups developing majors or degrees in Statistics should liaise with Computer Science with a view to including courses in programming fundamentals as well as computing languages/platforms that support data management and processing.

[4] https://www.science.org.au/files/userfiles/support/reports-and-plans/2016/mathematics-decade-plan-2016-vision-for-2025.pdf

The broader role of SSA in supporting the teaching of statistics at University

The working group felt that the Statistical Society of Australia needed to take a leading role in strategically supporting university teaching of statistics. There were two main areas of discussion that led to recommendations of the group.

i. **Teaching Award for Statistics.** While there are currently several awards for teaching, most are broad-based, sector-wide awards such as those offered by the Federal Government Department of Education and Training (formerly the Office for Learning and Teaching [OLT]). The Statistical Society of Australia should institute a prize for Tertiary Statistics Teaching to be awarded at its major conference. The group felt that the prestige of such a prize would be sufficient incentive and that a monetary award was not necessary. The award of the prize would be at the discretion of the SSA Awards Committee (which considers nominations for several existing awards) augmented by the Chair of the Statistical Education Section of SSA.

Recommendation:

The Statistical Society of Australia should award a prize for the Statistics University Teacher of the Year, annually. Nominations could be accepted from any person teaching a statistics course at any Australian university.

ii. **Revisiting Accreditation.**

Currently, the Statistical Society of Australia's accreditation scheme accredits University programs so that graduates of accredited program automatically attain status as Graduate Statistician (GStat). The Accreditation Committee accredits on the basis of program content, understood mainly in the context of coverage of statistical methods, both theoretical and applied. The working group identified that a variety of other skills are, however, sought by employers of statistics graduates, including communication skills and, increasingly, skills in database management and other computing skills outside traditional statistical computing skills. The working group therefore recommends that SSA conduct employer surveys that include questions about the skill sets employers would value and expect from statistics graduates, with a view to revisiting course accreditation criteria that reflect modern statistical practice. For example, the inclusion of course material focussing on communication, or the presence in major or degree programs of programming subjects useful in managing and processing data (e.g. Python, SQL, etc.), should be considered as appropriate for attaining accredited status.

Recommendation: Updating Course Accreditation requirements and practices

The Statistical Society of Australia should update its requirements for accreditation of programs and courses in Statistics leading to the status of GStat for graduates. This update should be informed by information gathered from employers of statisticians as to desirable skills/attributes for graduate to have, and should reflect the modern practice of statistics

including the development of strong communications skills and the increasing importance of computer programming skills for managing and processing data.

Recommendation: Advocacy from SSA

Further, the working group felt that the SSA should play a strong advocacy role for statistics in the public discourse surrounding statistical education and the role of statistics in light of the rapid development of "data science". The group noted that the American Statistical Association (ASA) has over the last few years played a prominent advocacy role for Statistics, particularly in the United States, and has recently released a statement about data science. The working group felt that the SSA should adopt a similar strategic advocacy role in the making of public statements and releasing guidance about the place of statistics in today's world.

STEMS-2016 Working Group on Postgraduate Statistics Education

The participants in this working group comprised academics from Australian, New Zealand and the US universities, as well as the Director of AMSI. They are listed later in this report.

A range of postgraduate programs

The group's first task was to define what is meant by 'postgraduate' education. For this purpose, it has been taken to include the following programs:

- Honours degrees
- Graduate Diplomas
- Master's degrees (by coursework or by research)
- PhD (taken to include professional doctorates as an overall label)
- Continuing Education

The design of new programs needs to take account of the varying destinations of graduates:

- Some graduates will be interested in eventually being in *decision-making* roles. As such, they will be users and interpreters of statistics and so will need a sophisticated knowledge of statistics and research to inform their jobs as strategists, managers, policy makers, and so on. Their educational needs will be furnished by a Graduate Diploma.
- Other graduates will pursue careers as analysts, involving technical problem formulation, modelling and analysis of data (mostly with established methods) and, importantly, communication of results. A Master's degree (*e.g.* Master of Applied Statistics) should provide them with the requisite skills, knowledge and knowhow.
- A third group will be interested in pursuing innovation – methodological developments and further research studies – with a view to taking up academic appointments or research positions in Government and industry. The Master's and PhD programs provide the appropriate courses of study for this purpose.

- A fourth group comprises teachers who may come from a variety of undergraduate backgrounds, and who seek professional development to enable them to teach at school, either teaching Statistics, or teaching other subjects (Science, Economics, …) where statistical understanding is important.

The capabilities of the graduates

Each of the programs should be designed to develop some core capabilities in its graduates, relating to professional development, scientific problem solving, principled statistical thinking and intuition, computational skills, and scholarly development.

A. Professional development
- Communication skills
- Appropriate non-technical skills
- Working in teams/collaboration skills
- Opportunities to learn how to teach
- Autonomy/independence
- Appreciation of ethics/confidentiality/legal/contractual aspects

B. Scientific problem solving
- Ability to translate research problems into and out of statistical formulations
- Experience with solving applied / real-world problems
- Interdisciplinary opportunities
- Understanding of the research process

C. Principled statistical thinking and intuition
- Understanding the limitations / boundaries of methods
- Statistical maturity
- Building statistical intuition and acumen

D. Computational competence and sophistication
- Foundations of computer science and programming
- Packages and coding
- Data bases, SQL, …

E. Scholarly development
- At least 25% thesis component in Master's program for PhD aspirants
- Good statistical education
- Able to read the literature

These capabilities will need to be developed to varying degrees, depending on the program.

Key characteristics of programs

To make a program attractive both to prospective students and to prospective employers of program graduates, it needs a number of key elements:

1. Individual flexibility
2. TEQSA compliant

3. Linked to the broader community of practice, which includes other statisticians as well as machine learners, data scientists.
4. Statistical group has critical mass
5. Producing graduates who are interesting and useful to employers
6. Highly networked and leveraged
7. Ability to take courses from cognate areas
8. Interdisciplinary
9. Experiential elements
10. Suitable for professional accreditation (of individuals and programs)
11. Clear entry requirements

Key planning milestones

Development of the new programs will need to be done in consultation – and, in some cases, the involvement of – a number of stakeholders, all of whom have a vested interest in the success of the programs. These include:

- Major employers
- Universities – top level and entry level
- Academies (AAS, ATSE)
- Program collaborators – external groups partnering in the provision of the program.
- Government/Public sector, *e.g.* ABS, ABARE, CSIRO
- Prospective students
- Data61 and machine learning community more broadly
- Cognate professional societies

A plan to develop and implement the programs (processes + funding models) for Masters / Doctoral / post-doctoral study will need to take account of the following aspects:

1. Appropriate accreditation processes prepared by SSA
2. Clarifying the key stakeholders and their needs
3. Development of models for delivering joint offerings (*e.g.* Biostatistics Collaboration of Australia – http://www.bca.edu.au/)
4. Guidelines for the construction of graduate programs
5. Communication plan
6. Development of a Business Plan to implement the programs

It may also be appropriate to run an annual STEMS event to help develop and maintain a public profile for Statistics Education.

How to move forward

All Australian-based participants in the original working group have agreed to participate, to varying extents, depending on their other commitments:

1. Geoff Prince
2. Jacqui Ramagge
3. Spiro Penev

4. Jean Yang
5. Louise Ryan
6. Jessie Roberts
7. Nicholas Fisher

Richard Arnold (Victoria University, NZ) would like to remain in touch with the work of the group. Other people may well be added to the working group.

Nicholas Fisher & Louise Ryan
Co-chairs, Working Group on Postgraduate Statistics Education