UNITING PRIMARY, SECONDARY & TERTIARY EDUCATION, INDUSTRY AND STATISTICS

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This paper describes a national project-based learning activity run in Australia and a collaboration uniting environmental sustainability and statistics which supports its delivery. The national initiative facilitates interdisciplinary interest, interaction and investigation engaging students from varied backgrounds and education levels. It develops key future workplace skills aligned with national school curriculum outcomes and motivates students by enabling them to take the lead, determine the context and self-assess. An underlying model connects industry, primary, secondary and tertiary educators, and technologies supporting wide-reaching communication and involvement. Australian school teachers are saying "21st Century learning at its best", "motivates and engages students". Industry mentors are saying "provides students a unique opportunity". Students are saying "engaging, educational and enjoyable". Over 1000 students engaged with the activity in 2017.

INTRODUCTION

There is a rising need for practical statistical expertise and understanding in the future STEM (Science, Technology, Engineering and Mathematics) workforce and across a number of university degrees. Students need to understand statistical concepts and acquire statistical skills to access and succeed in higher education and prepare for the working environment. Concurrently, reports identify the relative shortfall of adequately skilled individuals for the Big Data age (Manyika *et al*, 2011; Puang-Ngern, Bilgin, Kyng, 2017). Increasing numbers of students will need to engage with and become more greatly interested in the analytical, statistical and machine learning aspects needed to fill the growing need for such Big Data skills.

Early appreciation of, and engagement with, statistics is less than desired. The perceptions and general appeal of statistics, particularly for less quantitatively-minded students, requires educational techniques to enthuse students, maintain their interest and overcome initial hurdles to gain their interest or engagement (Howley, 2008; Howley, 2009). Statistical anxiety is a major impediment, even a deterrent for young people to access and succeed in university degrees (Onwuegbuzie & Wilson, 2003; Williams, 2010) and one that seems to particularly affect females and students from diverse backgrounds (Bui & Alfaro, 2011; Onwuegbuzie & Wilson, 2003). Early intervention for improving aspirations and pathways towards STEM and statistics disciplines and success within university for these cohorts is crucial, particularly for low socio-economic status (SES) students (Tai, Qi, Maltese & Fan 2006; Barnett, 2011; Maltese & Tai, 2010). Mathematical and statistical unpreparedness is a major factor affecting entry to and persistence in the STEM disciplines for students from low SES regions and culturally diverse backgrounds (Bonous-Hammarth, 2000; Clewell, 1992; May & Chubin, 2003). However, despite this research, and the proliferation of resources to teach *mathematics* available through digital media and the internet, data worldwide shows that *statistics* is still considered a significant roadblock for many low SES students (Bell, 2003; Petocz et al., 2007).

Australia's former Chief Scientist has commented that "when they do study them (the sciences) at school…the best way to teach inspirationally is to teach it the way it's practised." (Chubb, 2015). However, school teachers have rarely if ever experienced statistics in practice. Nor do they understand the varied and wide reach of statistical thinking, techniques and applications, and its importance to study design and inference. Their knowledge about the practicing statistician is at best limited, their focus has been on the many other topics and aspects of teaching. Not surprisingly when it comes to teaching statistics in secondary school, there is an increased focus by teachers on the theory or mechanics, rather than its practical applications, and statistics topics are taught in a manner not clearly part of a coherent whole. The relevance of the discipline to their

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areas of interest is lost, or at best unclear, for students; yet relevance is such a powerful motivator (Kember, Ho & Hong, 2008; Howley, 2008).

NATIONAL SCHOOLS' POSTER COMPETITION: THE 'STATS+X' INITIATIVE

This competition, delivered annually in Australia since 2014, is a fun, educational and engaging project-based learning activity that develops students' critical thinking, investigation, collaboration, communication, reporting and creative skills, and their awareness of how statistics, quantitative and scientific skills can help us better understand the world, no matter the field of interest. It engages students of all disciplines and taps into their interests, demonstrating the interdisciplinary nature of investigations, and maps to National and State Boards of Studies curriculum outcomes including but not limited to 'Data Collection and Representation', 'Single Variable Data Analysis' and 'Bivariate Data Analysis'. Significantly, the model, structure, resources and content for the national schools poster competition provides teachers the instruction, connection and support to enable achievement of each and all of the national curriculum's general capabilities, whilst enriching the teaching of the key topics in statistics through the practical and holistic focus.

Piloted in the Hunter Region in 2014 and expanding nationally in 2015, the project-based learning activity involves teams of 2 to 5 school students creating an informative poster presentation (akin to a conference poster) addressing a practical question on an area of interest to the students, from *any field* (the *X* in '*STATS + X*'), and utilising the collection, presentation and interpretation of data. There are five divisions representing school stages 2 to 6, with small cash prizes ($50 to $200) awarded to winning teams and schools. Example submissions are available at www.ssaipostercomp.info/winners.html.

Winners may be forwarded to the biennial International Statistical Literacy Project competition, with which it is aligned albeit with some key distinctions. One of the unique aspects of the national competition is the strategy of building an Australia-wide network of mentors to attend schools to facilitate the activity's delivery and engage students with discussions of the practical importance of statistics. With an increased number of out of field teachers in secondary schools, and the ever-increasing demands upon teachers, providing mentors and support mechanisms contributes to the competition's success.

Mentors are trained and supported nationally, guided by the national coordinator and the resources he has produced surrounding how to engage teachers and students and facilitate the activity. Mentors include undergraduates with experience in statistics, pre-service mathematics teachers, current and retired industry practitioners, academics and practicing professionals.

EARLY ENGAGEMENT – TERTIARY SUCCESS: SUSTAINABILITY MEETS STATISTICS

Building upon the national schools poster competition, an initiative combining it with the field of environmental sustainability was conducted in 2017, supported by the Commonwealth Government's Higher Education Participation and Partnerships Programme. The authors travelled to remote and rural areas of the state of New South Wales in Australia for a fortnight, visiting schools and running teacher workshops as part of the equity-oriented project.

The project aimed to engage students and teachers with innovative and industry-oriented practice, and assist those in low SES, remote and rural regions connect with, aspire to, and ultimately succeed in, higher education. The team delivered activities targeted at addressing barriers to higher education success, namely an understanding of science and statistics. Electric vehicles (and building mini electric vehicles), mushroom kits, designing clinical trials for new medicines, modelling human features in forensic anthropology and reflections about pizza (why is it that we can buy the same type of pizza from the same location on multiple occasions yet like it less than at other occasions?) were but some of the activities and discussions within this cross-disciplinary outreach in environmental sustainability (renewable energies), statistics and STEM.

Research Goals

The aim of the initiative was to support Stages 2 to 6 teachers (Grades 3 to 12) in remote and rural areas to actively engage students with authentic learning opportunities integrating sustainability, statistics & STEM concepts. In particular, to introduce such concepts to school

teachers and young audiences from low SES culturally diverse and remotely-located schools in a fun, educational and interactive manner via a project-based learning activity. It drew upon the successes of experienced tertiary educators and practitioners, in order to encourage and inspire:

- young minds towards increased: interest in investigations surrounding environmental sustainability and/or statistics in any field of interest; confidence in being able to contribute to the development of scientifically-rigorous sustainability pursuits (student voice); appeal of such scientific activity and the surrounding disciplines of statistics, sustainability and the sciences; feelings of such being 'accessible', within their reach;
- teachers towards an increased: understanding of the role of statistics and STEM in practice, and how to incorporate statistics within teaching the syllabus; feeling of support from and connection with higher education institutions.

Survey instrument

Online anonymous surveys of students and teachers (UoN ethics approval: H-2017-0090) were conducted prior to our visit and again several months after our visit, to assess the above. The surveys consisted of a series of statements to which students or teachers would indicate their level of agreement on a Likert scale (from 1 – very strongly disagree, through to 7 – very strongly agree).

Results

From this cross-sectional study, we had 71 students respond to the pre-intervention survey and 84 the post-intervention survey, whilst 34 teachers responded to the pre- and 29 the post-intervention surveys. Tables 1 and lists some of the survey items and the mean (and standard error) responses for the teachers and students respectively.

Table 1: Teacher mean responses pre- and post-intervention

ITEM	Mean_Pre	SE	Mean_Post	SE	%DIFF
I feel well-supported by Universities for developing Statistics activities	3.06	0.29	5.18	0.22	69.1%
I feel well-supported by Universities for developing STEM activities	3.13	0.29	5.14	0.22	64.6%
I feel able to connect with Universities to pursue innovative collaborations	3.25	0.32	5.21	0.24	60.2%
I feel confident in connecting students with valuable and practical examples of careers in Statistics	3.39	0.58	5.14	0.23	51.4%
I can see how I can combine Statistics with Environmental Sustainability projects	3.72	0.64	5.59	0.17	50.2%
Students are enthusiastic about Statistics	3.09	0.53	4.59	0.25	48.4%
I can see how Statistics and Environmental Sciences are valuable to one another	4.56	0.78	5.93	0.17	30.0%
I feel confident in connecting students with valuable, practical examples of Statistics	4.09	0.70	5.24	0.20	28.0%
Statistics is an important part of Scientific Investigations	5.09	0.87	6.10	0.21	19.8%

Table 2: Student mean responses pre- and post-intervention

ITEM	Mean_Pre	SE	Mean_Post	SE	%DIFF
I am involved, or have recently been involved, in projects focussed on Statistics	2.50	0.19	4.96	0.24	99%
I enjoy learning about Statistics	2.57	0.20	5.00	0.22	94%
I am aware of careers (or jobs) in Statistics	2.30	0.18	4.40	0.22	91%
I find Statistics interesting	2.87	0.22	5.16	0.21	80%
I am aware of how Statistics is used in the workplace to support investigations	2.91	0.23	4.95	0.21	70%
I can see how I can combine Statistics with Environmental Sustainability projects	3.00	0.21	4.79	0.19	60%
Statistics is very useful	3.68	0.24	5.70	0.17	55%
I would like to be involved in projects focussed on Statistics in future	3.30	0.20	4.78	0.22	45%
I would enjoy, or have enjoyed being involved in a project where I choose the topic and collect data to answer my questions	4.24	0.23	5.54	0.19	30%
I feel that people outside my school are interested in my ideas	3.34	0.21	4.31	0.20	29%
I would like to learn more about Statistics	4.38	0.23	5.29	0.21	21%

Across all aspects tested, both students and teachers responded more positively after our project than they did before. Teachers reported significantly more positive feelings of connection with and support from Universities with mean responses increasing in the order of 60%. Teacher recognition of the value of statistics, and importantly their confidence in feeling able to connect students with valuable practice both increased, the latter by some 50%. Teachers also reported an equally valuable increase in the enthusiasm of students towards Statistics.

Similarly, student participation and enjoyment in learning about statistics increased by as much as 90%, on average. Interestingly, students reflected positive changes, of some 30%, in aspects surrounding student voice and leadership, key points of focus on the initiative.

Some of the relative changes, for both teachers and students, weren't as large since the 'pre-intervention' mean scores were already quite high and thus the relative percentage improvement was smaller in magnitude. Importantly even those with higher pre-survey means increased post intervention.

DISCUSSION

The symbiotic aspects of STEM were reflected in an increased appreciation for Statistics (usually considered within the M of STEM) and its support of, and combining with, the Environmental Sciences and Electric Vehicles (which lies within and across the S, T and E of STEM). This supported one of the key aims of increasing the appeal and accessibility of Statistics through increased understanding of its collaborative and pervasive nature. The integrated nature of STEM is an important aspect, but also one that needs to be exemplified, and experienced by teachers, since teachers have understandably focussed in the past more so on their respective disciplines. The interdisciplinary workplace practice that industry and business personnel experience daily is not one teachers have necessarily experienced, or not to a great level. Nor do teachers necessarily have strong connections with tertiary institutions beyond academics in the Education Departments within which they have been trained. Thus interacting with, and bringing authentic learning experiences to, teachers and students is invaluable to help bridge this divide.

Teacher and student reflections upon the competition are very supportive of its approach, and identify how this outreach initiative and the associated competition is filling a void. In 2017, a

record 356 poster submissions were received, from some 955 participants, with even more engaging in the activity but not completing in time to submit a poster.

Such outreach initiatives are important for our discipline and the future STEM workforce. Connecting students with engaging and inspiring activities, and *demonstrating* the cross-disciplinary nature of statistics is invaluable to increasing interest in our discipline and supporting the growth of individuals and the society as a whole.

Relatively speaking, research surrounding outreach is an emerging area, and one that is complex given the many factors that may influence, both positively and negatively, students and teachers. The value of this particular project was the relatively focussed pre- and post-intervention survey approach, reducing the chance of other influential factors. Of course, the durability of these positive outcomes and consideration of underlying student and teacher factors are a matter for further research.

CONCLUSION

Connecting with teachers and supporting them is a valuable pursuit. An *arm's length* approach of expecting primary and secondary teachers to upskill alone to the point of piquing students' interests in statistics and driving students to further studies in the discipline, is fraught. Activities such as the national schools poster competition are designed to work collaboratively and develop support mechanisms. The challenge is to ensure that it is not left to the few to continue this charge, rather that all recognise the supply chain is only as strong as its weakest link and thus similarly unite in this charge towards addressing the needs of the Big Data Age.

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