Working Together to Improve Statistics Education: A Research Collaboration Case Study

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Abstract

In 2010 the statistics strand of *The New Zealand Curriculum* began to be implemented in secondary schools in New Zealand. This paper describes how a group of professional statisticians, statistics education researchers, and practising teachers worked together to produce curriculum support material that reflected modern and future statistical practice and that incorporated statistics education research findings about student learning. Since the approach to teaching statistics and the content was new, particularly in the area of statistical inference, we refer to how the group mounted two large consecutive two-year research projects, which were aligned with the staged introduction of the secondary curriculum in order to support teachers in the upcoming changes. With such a transformative change to the statistics curriculum we discuss also how the group needed to work on many other fronts to ensure key stakeholders in the education enterprise were conversant with the changes. This case study of a major change in a school statistics curriculum discusses the benefits of collaboration between statisticians, researchers, and educators and the challenges involved in trying to ensure that the curriculum was interpreted as it was intended and implemented successfully across the country.

Keywords: School statistics curriculum, curriculum development, education stakeholders, curriculum dissemination

1. Introduction

The New Zealand Curriculum (Ministry of Education, 2007) and the consequent changes in national assessment involve an industry of people employed to oversee and implement the changes for all subject areas. The new statistics curriculum, however, hides a small voluntary community of statistics educators interested in enhancing and changing their subject area to better reflect contemporary statistical practice, statistics education research findings, and the relevance of statistics to society and in ensuring a future generation of statisticians. The changes to the school statistics curriculum were possible because there was a community of people committed to changing the paradigm for the statistics content that is taught and for the approach to learning statistics. The community also realized that a review of the curriculum represented a 1 in 20-year opportunity, which needed to be seized at the time, to make significant advances in the curriculum, learning and assessment. In this paper we focus on how a small voluntary community of people attempted to improve statistics education through working together and collaborating with many people involved in the education enterprise and infrastructure.

2. Why change the school curriculum?

In 1992 a coherent mathematics curriculum from Years 1 (5 to 6 year-olds) to 13 (17 to 19 year-olds) was introduced for the first time. A review of this curriculum was conducted in 2004 resulting in a statistics curriculum literature review (Begg & Pfannkuch, 2004). Among the many recommendations for the statistics curriculum were that changes to the curriculum should build on the existing curriculum in an evolutionary way and that the emphasis be on statistical thinking and conceptual understanding. Begg and Pfannkuch (2004) noted that Jane Watson, an overseas expert, commented that the 1992 curriculum was “a leader in the world” and that NZ statistics educators wished to continue in this leadership role. In cognizance of the widening gap between statistical practice and school statistics education, the pervasiveness of technology in statistical practice, the call for more emphasis on statistical literacy, the exponential growth in statistics education research since the 1990s and its consequent curriculum implications, and the approximate 20 year longevity of the 1992 curriculum, NZ statistics educators realized they needed to envision and provide a *forward-looking* statistics curriculum for students.

3. What were the changes to the curriculum?

The major changes to the statistics curriculum were changing the emphasis: from skills to immersing learning within the PPDAC (problem, plan, data, analysis, conclusion) statistical investigation cycle; from how to construct plots to how to reason from and interpret plots; from hand-drawn plots to automated plots; from reasoning from descriptive statistics to reasoning about populations from samples and underpinning inferential concepts including an appreciation and awareness of sampling variation; and from a non-assessed and hence non-taught interpretation and evaluation of media reports to an assessed statistical literacy component.

4. Who was the group involved in driving the change?

The main vehicle for driving the change in the statistics curriculum was the New Zealand Statistical Association (NZSA) education committee. The committee comprised professional statisticians from across New Zealand but was augmented with statistics education researchers, school and tertiary teachers, and teacher professional development facilitators to assist with and respond to the curriculum changes. Within this group four people played particular leadership roles. Mike Camden, Statistics New Zealand, domiciled in Wellington where the Ministry of Education is situated was "the ear on the ground" for any Ministry-led initiatives such as learning that a review of the curriculum was being conducted, and as organizer of the committee played a vital role in ensuring that regular meetings occurred. Pip Arnold, a teacher professional development facilitator, had far reaching teacher networks across NZ and was active in curriculum and assessment development, on which she sought comment and advice from the committee. Chris Wild, a university statistician, had knowledge about how the discipline of statistics was changing and the implications for the school curriculum. Maxine Pfannkuch, teacher turned education researcher, had knowledge about research in statistics education and its consequent implications for the curriculum. All these people had been involved in promoting and working on statistics education issues for many years driven by intrinsic interest, passion and a caring about statistics education being real and relevant to students.

5. How did the group facilitate the change?

Two key factors were involved in facilitating the change, the setting up of two major research collaborations and engaging with key stakeholders.

Two collaborative research projects

Background. Because of national assessment for qualifications at Years 11, 12 and 13 there was a staged introduction of the curriculum into secondary schools with the Year 10 cohort starting the curriculum in 2010. Since the approach to teaching statistics and the content was new, particularly in the area of statistical inference, we realized that we needed to design resource materials and develop free analysis and concept building software specifically designed to support the desired learning, as most NZ schools cannot afford commercial software. For teachers to feel confident about the changes and using the resources, research evidence that students from a diverse range of schools were capable of learning the new content was essential. Hence we successfully bid for a two-year research project from 2009 to 2010 that covered Years 10 and 11 with some work on Year 12 so that we were one year ahead of the curriculum change (Pfannkuch, Arnold, & Wild, 2011). Similarly we mounted another research project from 2011 to 2012 covering Year 13 and introductory university statistics (Pfannkuch, Forbes, Harraway, Budgett, & Wild, 2013).

Apart from the actual research and development we wanted to grow teacher leadership capacity and teacher interest in statistics education, since a small group on its own cannot effect change on such a large enterprise. Hence to disseminate information arising from the projects we used existing events (e.g., the Annual Statistics Teachers Day in Auckland), websites (e.g., Census at School), and networks (e.g., NZ Teacher Professional Development Facilitators for Mathematics). There was also an expectation from the outset that all people involved in the research projects would give presentations and workshops, with support provided to enable them to present confidently either on their own or in pairs.

Building a diverse team. The first Auckland based project had two statisticians, two education researchers, and nine teachers on the team. The second NZ wide project team comprised three statisticians, two researchers, 16 Year 13 teachers, seven university lecturers, one workplace practitioner, three teacher professional development facilitators, and one quality assurance advisor. The first project team was built through using our networks to identify potential teacher leaders and inviting them to participate whereas for the second project an open invitation to participate was given to all teachers at the Annual Statistics Teachers Day. Although the teams were enthusiastic about statistics education there were several characteristics of the team and people within the team that we felt contributed to the success of the collaboration.

The characteristics of how the team worked together, particularly in the smaller first project, were an open process and willingness to debate and challenge ideas. That is, people were not simply consulted on prepared resources, rather they were involved in the struggle to identify conceptual foundations and to design effective learning approaches and tasks. Members candidly expressed their opinions from their perspective, leading to very robust debates, going away and rethinking issues, then engaging in more debate. At the back of everyone's minds was that solutions to the problems encountered and raised needed to be found within a time frame. In this way a consensus was built about what learning was practically possible for teachers and students. The characteristics of certain people in the teams also served to help the collaboration. Five main characteristics were: the software conceptual developer who focused on statistical learning as well as analysis; the worrier who monitored and argued intensely about language and conceptual ideas conveyed through language; the creative task designer who understood how students learned and developed concepts; the experienced teacher who knew about his/her students and other teachers' capabilities and practical classroom constraints; and the domain knowledge provider who could give insights from the perspective of the statistics discipline and statistics education research literature.

Conduct of the projects. The first project centred on building Year 10 and 11 students' knowledge of inferential reasoning namely ideas such as sample, population, sampling variability, sample size effect, and developing informal guides for making a judgement in comparison situations about whether one group tended to have bigger values than another group (Arnold, Pfannkuch, Wild, Regan & Budgett, 2011; Wild, Pfannkuch, Regan & Horton, 2011). The second project focused on developing Year 13 and introductory university statistics students' ideas of sample-to-population inference and experiment-to-causation inference. These ideas were developed using computer-based empirical methods using the bootstrap method for quantifying confidence intervals for population parameters and using the randomisation test for deciding whether the treatment was effective in experiments (Budgett, Pfannkuch, Wild, & Regan, in press; Pfannkuch, Wild, & Parsonage, 2012). Both projects involved development of innovative dynamic visualisations, hands-on activities, new verbalisations to describe previously unseen phenomena (e.g., chance is acting alone, variation band) and to capture identified concepts that had not been previously taught (e.g., back in the populations), and resource material.

The methodology employed in both studies was design research. This research involves designing learning trajectories that engineer new types of statistical inferential reasoning and then revising them in the light of evidence about student learning and reasoning. Design research aims to improve learning and provide practitioners with accessible results and learning materials. Using Hjalmarson and Lesh's (2008) design research principles the development process in these studies involved two research cycles with four phases: (1) the understanding and defining of the conceptual foundations of inference, (2) development of learning trajectories, new resource materials, and dynamic visualization software; (3) implementation with students; and (4) retrospective analysis followed by modification of teaching materials. Such a design was eminently suitable for curriculum innovation because it allowed for a testing of ideas and a revisiting of problematic issues.

Both studies were conducted over two years and went through two developmental cycles. The main data collected were pre- and post-tests of students (200 students in first project and 3000 in second project), pre- and post-interviews with students, videos of classes implementing the learning trajectories, and teacher reflections. Findings from the students' data resulted in many issues needing to be rethought, a deeper struggle by the research team to reveal the complexity of the underpinning thinking, and new issues to be addressed such as Year 10 and 11 students' impoverished understanding of distribution and Year 13 and introductory university students' understanding of uncertainty. Hence the data from the students fed into revisions of the learning approaches and the resource material.

Dissemination and communication. For the first project, findings were disseminated at the Annual Statistics Teachers Day in Auckland with one statistician and two education researchers from the project team presenting the plenary about findings from the research and all teachers in the project running parallel workshops, which all the participants (180 teachers) were required to attend. The following year was similar except that this time the teachers in the project were the plenary speakers telling their stories of trialing the new material for the curriculum. Since the teachers came from decile 1 to decile 10 schools (a decile 1 school has students from the lowest socio-economic level while decile 10 has the highest), the power of their stories cannot be underestimated in allaying teachers' fear of the changes. All material for both these days including recordings of the plenaries was made available on the Census At School website (www.censusatschool.org.nz). A similar pattern of dissemination was used for the second project except by this time attendance had to be limited to 350 teachers with teachers wanting to come from other parts of NZ. A contributing factor to the increased attendance was that the changes in the curriculum and assessment had started and teachers were more aware that they needed information and professional development for the upcoming changes in the next year level. Teachers in the project were also raising teacher interest through running workshops at the local level across NZ using existing networks such as regional mathematics teacher associations. Following the Annual Statistics Teachers Day the team mounted a "Road Tour" in 2012 of the other main population centers in NZ in an attempt to ensure the changes in the Year 13 statistics curriculum were understood. The "Road Tour" involved a plenary and 11 workshops and was organized in conjunction with regional mathematics teacher associations. Including Auckland about 700 teachers attended the days.

The first project was Auckland based but the second project needed to be nationwide if the substantial changes to the Year 13 statistics curriculum (a full year course rather than a component of a mathematics course as it was in Year 12 and below) were to gain traction amongst teachers. Fortunately some teachers from schools across NZ asked to be part of the second project to the extent that they were willing to fund their own trips to Auckland, a situation caused by funding constraints. We believe that this desire to be part of the research project was partly attributable to our engagement with and dissemination of research findings to teachers at the Annual Statistics Teachers Day in Auckland and international presentations.

One unexpected outcome of the research collaborations was the engagement of some project team teachers in research under our supervision, which augmented the research project and implementation of the new curriculum beyond the boundaries originally considered possible. For the first project posing questions for investigations leading to inferences, and creating awareness of distribution at the year 10 level were tackled in a PhD thesis. For the second project three teachers used existing teacher study awards to engage in research. The first teacher did a masters thesis on developing Year 13 statistical literacy, part of which built on the bootstrap part of the project, while a second teacher developed her own knowledge and resources for the Year 13 time series topic building on her prior professional experience in a national statistics office and using a new module in the software developed for the project. A third teacher is now underway to study more about experiments and the randomization test, a new topic in the Year 13 curriculum. Another unexpected outcome was that some project team members became networked into curriculum and assessment development at the Ministry level and hence became part of facilitating the changes there.

Engagement with key stakeholders

Dissemination to teachers of the new learning approaches, verbalizations, visualizations and research findings was only part of the enterprise we had to deal with. After the NZSA education committee had given feedback on assessment standards, which assess and are linked to the curriculum, and the standards were put in place another problem arose. The Ministry of Education and the New Zealand Qualification Authority employed contractors to write assessment exemplars for each standard for the national qualifications. It soon became apparent that professional development of these people was also urgently needed and we needed to engage with them. This situation was not surprising as the changes were outside the realm of teachers' experiences and textbooks available, even internationally. A series of written submissions and rewriting what we thought the assessments should be to reflect the intentions and interpretation of the assessment standards and curriculum was necessary. Some exemplar writers sought help and advice from the committee, which resulted in invaluable exchanges of ideas and discussions while others remained anonymous. Other key stakeholders such as assessment moderators, resource writers, professional development facilitators and private providers engaged with us at varying levels as knowledge-domain experts. Changing a curriculum from the outside within an enormous established conglomerate of vested interests and deadlines is fraught with pitfalls including understanding how the system actually works. Only by keeping our ear to the ground and reacting quickly and positively to any Ministry statistics curriculum and assessment output could we keep tabs on the Ministry-led implementation of the curriculum. With the NZSA education committee and the research project group people we managed to share the load of responding to an enormous number of documents and queries.

6. Reflection on the change process

When reflecting on this case study of working together to improve statistics education the following main themes emerged about how the collaboration became operable.

- A core group involved in all parts of the change process from the curriculum review to implementation.
- Building bridges between stakeholders and turning them into collaborators. That is, bridging the divide between statisticians, university lecturers, education researchers and teachers, and bridging the divide between statistics practitioners/teachers and people within the Ministry infrastructure.
- Working together around a common goal through the authoritative expert body of the NZSA that aimed to assist and monitor the change process and research projects that aimed to turn curriculum words into classroom practice.
- Disseminating information constantly to teachers even if findings or the products were not fully fledged to keep them in the "thinking loop."
- Growing teacher leadership capacity and interest in statistics education to enable sustained teacher and curriculum development.

The jury remains out on the extent of the success of the full implementation of the NZ statistics curriculum. As was expected the transition to the new curriculum has not been without problems and only time will tell, as teachers become more familiar with the import of changes, the extent to which the new approaches to learning statistics will translate into improved student thinking and reasoning and close the gap between statistical practice and school statistics. The task now is to keep the momentum of teacher interest in statistics education and collaborative problem solving going. Teachers have already approached us to revamp the probability part of the curriculum and many others, particularly the research team members, have indicated they want to be involved in our next research project. Such support for improving statistics education was made possible through working together.

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