STATISTICS TEACHING AND LEARNING: THE NEW ZEALAND EXPERIENCE

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New Zealand has recently published a new curriculum encompassing all eight learning areas. One of these areas, Mathematics, has been re-named Mathematics and Statistics to emphasise the changes needed in both the pedagogy and thinking behind statistics education and the urgent need for statistic education for critical citizenship. This momentous change has been accompanied by a corresponding emphasis on statistical thinking, statistical literacy and probability. Couple this with the increase in teaching time which is to be devoted to statistics, and huge changes have taken place. Their full implications are yet to be felt.

BACKGROUND

In November 2007, the overhauled New Zealand Curriculum (Ministry of Education, 2007) was published. It covered all eight learning areas and the thirteen years of school from the age of five. It had been published in draft form for over a year for feedback from interested parties who ranged from teachers through to curriculum designers. After many thousands of submissions the draft became the actual curriculum, but something quite wonderful had occurred; the Mathematics Curriculum of 1992 (Min of Ed, 1992) had become the Mathematics *and Statistics* curriculum of 2007.

NATIONAL CURRICULUM

In the 1992 version of the mathematics curriculum there were six strands, mathematical processes, number, algebra, measurement, geometry and statistics. In the 2007 version there are only three strands. Number and algebra (N & A) have been combined, as had measurement and geometry (G & M), with statistics (S) (incorporating probability as it had done before) as the third strand. The first strand of mathematical processes has now been infused throughout the levels and strands. A Venn diagram was used (how appropriate for mathematics!!) to show the emerging importance of statistics in time allowance for teaching. Shown below (table 1) are diagrams to illustrate this increasing emphasis on statistics as a child moves through the years.

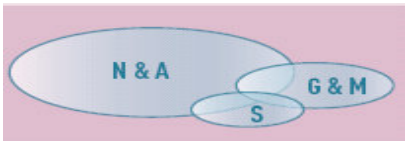
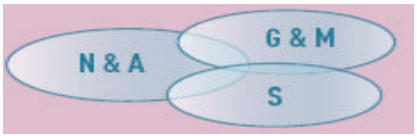
Approximate ages		Curriculum Level
Ages 5 - 9		Levels 1 & 2
Ages 8 -14		Levels 3 & 4
Ages 13 -16		Levels 5 & 6

Table 1

During the first years of schooling, statistics, while an important part of the curriculum, can be seen to be the junior partner in terms of the time devoted to the teaching of it. During the middle years this increases so that statistics has an increasing importance commensurate with that of geometry and measurement, but number and algebra still has the largest share. In the senior school all three areas are as important as each other. This has really important implications for the revamping of work schemes by departments. Statistics had been given less than full time in previous years. Some schools would devote perhaps 6 weeks to statistics from a 40 week teaching year which is about 15% of the time allowance. Now in the secondary school, if statistics is to get about a third of the teaching time that would equate to some 13 weeks of teaching statistics and probability. This doubling of teaching time will present many challenges for teachers and curriculum planners. If more time is devoted to one area of the curriculum, another will have to lose teaching time. This will be a real challenge for all New Zealand schools. What they teach and how they teach is will be crucial to the success of this initiative. This point will be enlarged upon later.

Below is a diagram from the new curriculum (pp 44) which shows the school years arranged horizontally at the bottom. New Zealand children start school at aged 5 and if they stay for all the years they will leave after year 13, 17 or 18 years of age. This diagram is included because our curriculum is arranged in levels, and the fade-in fade-out lines indicate the variability of ages which children can be expected to interact meaningfully with different concepts. So there are eight levels of the curriculum, and typically children take between one and two years to move between levels.

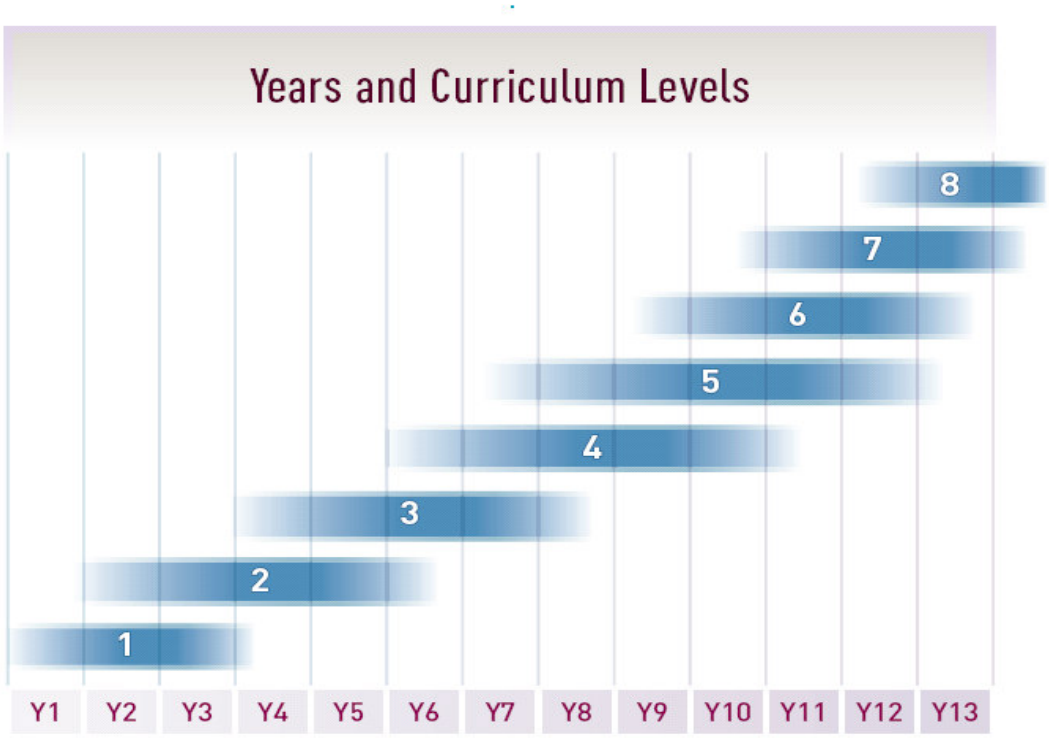


Table 2

…AND STATISTICS

The conditions that led up to the momentous changes within the statistics curriculum, including the name change, were building up in New Zealand since the previous curriculum was produced in 1992. Teachers and students were encouraged to bring contextually important, authentic and relevant statistics into classrooms. In the 1992 curriculum before each set of

Achievement Objectives (statements about what students should be able to achieve after appropriate learning experiences) was written 'within a range of meaningful contexts, students should be able to…' In 2007 this had changed to 'In a range of meaningful contexts, students will be engaged in thinking mathematically and statistically.' The change was made to reflect the difference between deterministic (mathematical) and stochastic (statistical) thinking. The inclusion of statistics in the title of this teaching area reflects the increasing importance of using and interpreting data as part of critical citizenship.

In the 1992 curriculum the Achievement Objectives (A.O.s) stemmed from 3 main headings and these have been changed, in what may look like a small way, but the differences are redolent with meaning for teaching. Table 3 below shows these:

1992	2007
Statistical investigations	Statistical investigation
Interpreting statistical reports	Statistical literacy
Exploring probability	Probability

Table 3

STATISTICAL INVESTIGATION

All the A.O.s from level one to level 8 contain the words *using the statistical enquiry cycle*, a discussion of which is included later, but suffice to say at this point that it is considered important enough to adopt this cycle unequivocally. The A.O.s vary, at level one stating that children will

- Conduct investigations using the statistical enquiry cycle…

This changes at level four to

- *Plan and* conduct investigations using the statistical enquiry cycle…

And changes again at level 5

- Plan and conduct *surveys* and experiments using the statistical enquiry cycle…

And by level 8 this becomes

- Carry out investigations of phenomena, using the statistical enquiry cycle…

After each of these statements are further bulleted-points detailing the type of work they are expected to do. One of the biggest changes is in the need for students to pose and answer their own questions, and again that will be further illustrated during the PPDAC Cycle section.

STATISTICAL LITERACY

Statistical literacy is now the title under which all the interpretation, inferences and sometimes subliminal interference within statistical reports resides. Even in the first year at school statistical literacy has an A.O.:

- Interpret statements made by others from statistical investigations and probability activities.

It is interesting to see the other two A.O.s are referenced in this one.
The statements become more sophisticated as they move through the years. The A.O. at level 6, which is approximately school year 11 or aged 15 or 16 years:

- Evaluate statistical reports in the media by relating the displays, statistics, processes, and probabilities used to the claims made.

PROBABILITY

While probability has undergone a vast change it has not be accompanied with all the support materials and research documents which the statistical areas have and therefore will not be described in detail except to show an example of the changes. From level 1, in 1992 the achievement objective was:

- Classify events from their experiences as certain, possible, or impossible.

In 2007 the achievement objective is

- Investigate situations that involve elements of chance, acknowledging and anticipating possible outcomes.

Overall the new curriculum has made a change to active investigation of probability situations.

KEY COMPETENCIES

The introduction of thinking as so central to statistical investigations brings in another area of interest from the 2007 curriculum. These are the key competencies (Min of Ed, 2007, pp12.) which are characterized as capabilities for living and lifelong learning. The Key Competencies have areas highlighted in italics which show qualities central to effective statistics teaching and learning. These are shown in table 4 below.

Key Competency	Explanation
Thinking	*Thinking* is about using creative, critical and metacognitive processes *to make sense of information*, experiences and ideas. These processes can be applied to purposes such as *developing understanding, making decisions, shaping actions*, or constructing knowledge. *Intellectual curiosity* is at the heart of this competency. Students who are competent thinkers and problem-solvers actively seek*, create* and use knowledge. They reflect on their own learning, *draw on personal knowledge and intuitions, ask questions, and challenge the basis of assumptions and perceptions.*
Using language, symbols and texts	Using language, symbols and texts is about working with and making *meaning of the codes in which knowledge is expressed*. Language and symbols are systems for representing and communicating information, experiences, and ideas. People use languages and symbols to produce texts of all kinds: written, oral/aural, and visual; informative and imaginative; informal and formal; *mathematical, scientific, and technological.* Students who are competent users of language, symbols and texts can *interpret and use words, number, images, movement, metaphor, and technologies in a range of contexts.* They recognise how choices of language, symbol, or text affect people's understanding and the ways in which they respond to communications. They confidently use ICT (including, where appropriate, assistive technologies) to access and provide information and *to communicate* to others.
Managing self	This competency is associated with self-motivation, a "can-do" attitude, and with students seeing themselves as capable learners. It is integral to self-assessment. Students who manage themselves are enterprising, resourceful, reliable, and resilient. *They establish personal goals, make plans, manage projects, and set high standards.* They have strategies for meeting challenges. They know when to lead, when to follow, and when and how to act independently.
Relating to other	Relating to others is about interacting effectively with a diverse range of people in a variety of contexts. This competency includes the ability to listen actively, recognise different points of view, negotiate, and share ideas. Students who relate well to others are open to new learning and able to take different roles in different situations. They are aware of how their words and actions affect others. They know when it is appropriate to compete and when it is appropriate to co-operate. *By working effectively together, they can come up with new approaches, ideas, and ways of thinking.*

Participating and contributing	This competency is about being actively involved in communities. Communities include family, whanau, and school and those based, for example, on a common interest or culture. They may be drawn together for purposes such as learning, work, celebration, or recreation. They may be local, national, or global. *This competency includes a capacity to contribute appropriately as a group member, to make connections with others, and to create opportunities for others in the group.* Students who participate and contribute to communities have a sense of belonging and the confidence to participate within new contexts. They understand the importance of *balancing rights, roles, and responsibilities and of contributing to the quality and sustainability of social, cultural, physical, and economic environments.*

Table 4

PPDAC CYCLE

The PPDAC Cycle is at the very heart of New Zealand's curriculum changes for statistics teaching and learning. Below is the poster which exemplifies the stages of the cycle. This poster is available to download in this format or with an older central character from the web site www.cencusatschool.org.nz. This website has a myriad of resources and teaching ideas to aid teachers and students in exploring the ideals of the new statistics curriculum.

The five stages of the PPDAC Cycle are briefly described below in table 5.

PPDAC	Aspect	Explanation
Problem	understanding and defining the problem	This area involves the student right from the inception of the work. There is space and time given to thinking about something interesting to investigate, and although asking the question is one of the most difficult areas in the cycle it ensures that the activity is authentic. The student decides on terms of reference, and begins to own the work, very much as a research statistician might.

	how do we go about answering this question?	Once the question is asked then the student needs to find a pathway through and this leads to the development of a plan.
Plan	what to measure and how?	These are further decisions which the student has to make. There may be an iterative process going on here as the student wrestles with these decisions.
	study design?	More decision-making, and introducing the idea that there is a methodology to employ, and those different decisions can make for different results, and effect reliability and validity.
	recording?	How will the data be recorded? Will a data-capture sheet be required, again the student is at the centre of all decision making
	collecting?	Will the student literally collect the raw data, or will existing data be hunted-out and used, perhaps in novel ways?
Data	collection	The student carries out the data collection part of the plan
	management	When collecting raw data there are many management issues which range from the handling and organising of large amount of data points, to the storing of such data in, for example, spread sheets.
	cleaning	Some methodology, such as self measurement by students, can lead to very varied results, with some datum points falling outside the set of expected results, hence the need to clean the data. One such difficulty is routinely encountered when using typical dress-making tape measures. These frequently have centimetres on one side and inches on the other, and of course the use of a mix will cause very varied results.
Analysis	sort data	Here the raw data will be data-mined after some gathering and perhaps ordering by some factor
	construct tables, graphs	This is the traditional area of statistics activities in schools. Typically text-book based and typically used in examinations as being clear-cut evidence of some analytical routine. Central tendency and spread are big factors here.
	look for patterns	Observing how the raw data might have perhaps a harmonic quality, or something similar.
	hypothesis generation	Here a student will be taking the first tentative steps towards explaining some of the observed patterns or trends
Conclusion	interpretation	Only in authentic tasks does this have any validity. Here a student will look at the gathered and analysed data and try to make some sense of the story which the data is telling.
	conclusions	Obviously students will be drawing on the story told by the data and making connections to some tentative causality perhaps, or reasons.
	new ideas	Having progressed through the cycle, a rich authentic set of data will inevitably have other partial stories to tell and this will present itself to the student as a fresh avenue to explore.
	communication	This area was almost completely missing when all the student had to do was draw a graph or find reasons for using mean, median or mode. Now the student will be using their statistical literacy aspects to write about what they did and what they found out.

Table 5

ACTIVITIES AND PEDAGOGY

This type of investigative learning has huge implications for the type of pedagogy a teacher will employ and the type of deep conceptual understanding which might take place within the student. Below are examples of rich activities which enable this to happen.

How Faithful is Old Faithful?

This is an activity developed and written by Michael Shaughnessy and Maxine Pfannkuch (2002). The article details some of the desired ways of working and shows some of the outcomes via student work. The whole article is very informative and discusses variation and statistical thinking (Pfannkuch & Wild, 2003). This activity has been successful in classrooms ranging from year 9 to 13, and has always generated interest and curiosity. Again the communication side of the work can be from drawing giant graphs to illustrate a groups' thinking to the presenting of findings with the aid of perhaps a power point and in depth analysis to the whole class. This type of activity illustrates to students part of the PPDAC Cycle, and perhaps acts as a catalyst for students asking their own questions which they use existing data sets to answer.

An Unusual incident

This is a worksheet containing data from a real disaster which took place in the early part of the 20th century. Students are expected to look at the data, find interesting patterns, make conjectures and discuss these with fellow students. With careful consideration of the data students do gradually agree about what the unusual incident could be. Once they have discussed this they can be encouraged to write a report of the data, perhaps in the style of a newspaper report of the time. There are many different outcomes to the communication section, but it communication is important in the New Zealand curriculum, and so it is emphasised here. The worksheet and extra supporting documentation can be found at http://exploringdata.cqu.edu.au/unusual2.htm.

The Monty Hall problem

If this title is inserted in a search engine huge numbers of sites will be available for exploration, and after the class has been investigating this phenomena these sites can provide powerful ideas and discussions for students to take as far and as deeply as they require. This activity is probably best started from the site found at http://math.ucsd.edu/~crypto/Monty/monty.html. Here you can find an applet (small application contained within the site) which allows the students to play the game, and try to win a red sports car rather than a donkey. Also on the site is the information about a controversy which happened in the 90's in America about the game show Let's Make a Deal when people vehemently disagreed about what was the best strategy for winning the car.

The solution to the problem is counter-intuitive. This challenges students to use their probabilistic thinking and to use simulations to prove their argument. Investigating the situation and realising that at times ordinary people and statisticians have had interesting discussions about probability can again be informing and enlivening. Again the students need to communicate their results and again requires far more variety of presentation than merely the student's work book.

Applets

To find more applets merely search for them on any search engine. These sites listed below are a small selection of the types of applets available on the World Wide Web for teachers to use to enliven their lessons and to enthuse their students.

http://www.shodor.org/interactivate/activities/AdvancedMontyHall/
http://probability.ca/jeff/java/utday/
http://www.stat.sc.edu/~west/javahtml/Histogram.html
http://wise.cgu.edu/links/applets.asp

NEW STATISTICS COURSE

In 2005 I was charged with writing a new one semester course from a given outline, for teaching statistics at the senior secondary level, years 12 and 13 where students are aged approximately 17 to 18 years of age. Having read a great deal in my preparation for the course I realised that statistical thinking was very much in line with my own preferred style of teaching and it legitimised my investigative style of teaching. Use of technology had always seemed prerequisite in teaching statistics, from graphing packages to graphing calculators, through dedicated software like Tinkerplots and Fathom to specific software like R made available through the University. Interactive white board and interactive applets available on the World Wide Web added another whole dimension to the mix.

This course is designed to give pre-service teachers good grounding in the final two levels of the curriculum. The years 11, 12 and 13 are the years of examinations, both external and internal, and for achieving university entrance qualifications. However it has not been possible to concentrate just on these final years, the years of confidence intervals and sampling, of interpreting risk and time-series. The course instead assumes no specific content knowledge, no particular background in statistics and inducts the student teachers into statistics from the very beginning, tracking them through so that by the time the end of the semester arrives, they have become knowing in the ways of the senior students.

This exposition and description of the statistics within the New Zealand Curriculum was occasioned by a visit to Japan in January to give a talk at a symposium about the New Zealand experience and to help them begin the process of writing and implementing a completely new statistics curriculum. Currently they do not have a strong statistics teaching tradition and their national curriculum has not given it any particular place within schemes. Japanese teachers and statistics educators are currently engaged in a curriculum stock take, and any re-writing that takes place will hopefully incorporate statistical thinking and statistical literacy and probability.

All the information regarding the New Zealand Curriculum can be found on http://nzcurriculum.tki.org.nz/ and the whole curriculum can be downloaded from that page. The TKI site is also worth exploring for resources to support these changes to statistics education.

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Shaughnessy, M., & Pfannkuch, M. (2002). How faithful is old faithful? Statistical thinking: A story of variation and prediction. *Mathematics Teacher, 95*(4), 252-259.