Process Skills & Statistical Education

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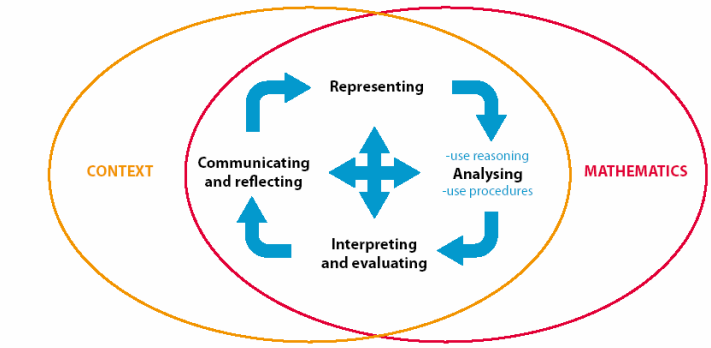
In the UK there is a new National Curriculum where procedural techniques are given much lower prominence and subject content greatly reduced. There is greater emphasis on skills and processes that individuals can use in order make all young people successful learners, confident individuals and responsible citizens. I shall illustrate how this is an opportunity for statistical education to play a greater role both within mathematical education and also in cross curricula dimensions and important personal, learning and thinking skills. Within the mathematics curriculum the key processes have a great similarity to the Statistical Problem Solving Cycle and offer us the incentive to drive statistical education forward. I shall explore ideas and possibilities for ways to engage on the next steps forward. The paper may have a UK emphasis but the vast majority of ideas included are easily transferable to other countries and different school settings.

In the UK the new National Curriculum states that problem solving lies at the heart of mathematics and involves a cycle of processes, referred to as the key processes. These process skills help learners both to learn the mathematics and to apply this knowledge to situations they will meet in life and in the world of work. Does this sound rather familiar? In fact, when you further examine the details of the key processes, the similarity to the Statistical Problem Solving or data-handling cycle becomes even more explicit. Mathematics, which includes statistics, has 4 key process skills listed: '*Representing'*, *'Analysing'*, *'Interpreting & evaluating'* and finally '*Communicating & reflecting'*. In the governments National Strategy Guidance papers (2008) the following diagram is given to show how the process skills are related to each other and interact with both the context and the mathematics itself.



The similarity to the Statistical Problem Solving Cycle does not stop there and much that the UK government go on to say about the reasons for the changes to the National Curriculum will resonate with statistical educators across the world. They say that in order to function mathematically all learners need to experience situations that are;

- Increasingly complex, including non-routine or multi-step problems and extended enquiries.
- Unfamiliar so that they can learn to transfer the skills they learn
- Opportunities to develop greater independence and autonomy in problem solving skills so that they can choose to select and apply the mathematics they wish to use for themselves.

This is all very commendable and something that as a statistics educator I would endorse, however, if you explore the new curriculum further within a section called 'Range and Content'

you will find 'statistics' split into four sections for 11-14 year olds and four sections for 14-16 year olds. As might be expected 3 out of these 4 sections are the handling data cycle, measures of central tendency & spread and probability. However the final section – presentation and analysis continues to include such named techniques as histograms and cumulative frequency. What I find very hard to understand is why, when their stated objectives are for young people to only apply transferable skills and to have autonomy and independence of thought, they insist that they have to learn how to plot a cumulative frequency curve or construct a histogram with unequal intervals? Why are specific techniques named at all instead of a more generalised statement given? It seems as if we are still of the opinion that McLean (2000) expressed that statistics is simply a set of techniques to aid in decision making? In many other countries, such as New Zealand, their national curriculum does not mention actual techniques by name at all putting the emphasis very firmly on determining appropriate variables, measures and presentation and the evaluation of statistical information, interpreting risk and investigation of situations involving chance. In fact its stated primary aim for mathematics education is "the need for mathematics to be taught and learned within the context of problems which are meaningful to students and which lead to understanding of the way mathematics is applied in the world beyond school." This seems to make much more sense.

A further issue to consider is that in many countries across the world the teachers delivering the statistics curriculum are mathematics teachers who often have a very different, or mathematical, approach to statistics and who are more confident when dealing with the transmission of techniques rather than elements of statistical literacy. They also find it easier to deal with techniques in isolation and do not feel the pressure, as many statistical educators do, to always place the use of techniques within a meaningful and relevant context.

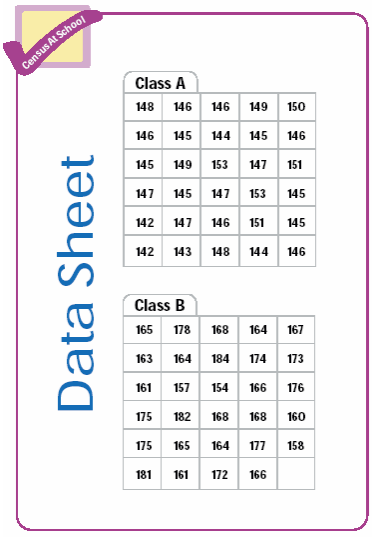
Personally I have never been able to find many useful applications of either cumulative frequency graphs or histograms with unequal intervals which does go some way to explaining why I find their inclusion by name in the curriculum so strange. While the new process skills really concentrate on those usable transferable skills that can be transferred to problem solving contexts the enforced use of particular techniques seems to clash heavily with the aims and objectives of the curriculum. We need to concentrate on ensuring that learners think and reflect on the skills they are developing and on understanding when and why they are using certain techniques rather than mechanical procedures. In 2006 Mckenzie & Goldman, following their reading of the GAISE report which has very similar aims to those I refer to above, analysed questions in textbooks and examinations for Introductory statistics courses at Universities in the USA and found the great majority of the questions to not be conceptual in nature. Jane Watson from Tasmania has also done much research on children's understanding of statistical concepts and finds over and over again that children are using techniques with little or no understanding of the concepts involved. (See Watson (2006) for examples).
While taking workshops for mathematics teachers and those currently in teacher training I place a great emphasise on the differences between the mathematical aspects and techniques used within statistics and the statistical concepts behind the understanding. I encourage participants to consider a number of scenarios, often taken from the media, and challenge their own levels of thinking and understanding of statistical concepts. This will usually result in them quickly coming to a realisation that we are not helping our children develop as confident and aspiring members of society if we are failing to get over to them the need to question figures and statistics presented to them and not to challenge and probe:

- where data has come from;
- who was asked?;
- what time period are we talking about;
- what evidence have we got;
- who gathered the evidence;
- when was it gathered;
- what questions where actually asked;

- etc etc etc .

Once they are put into the position as learners themselves it quickly becomes apparent to them that the understanding of the basic concepts involved is far far more important than the actual techniques being used. Once they start to ask questions and not accept on face value they become empowered and start to think clearly and confidently. This is the power of statistical literacy and a message that is vitally important. Especially if we are in the position, as the UK and many other countries currently are, that Statistics is a subset of the mathematics curriculum and often taught by mathematicians who are not trained in statistics nor appreciate its pedagogy.

In the CensusAtSchool project we produce many curriculum resources for teachers. Right from the outset of the project in 2001 one of the most popular ones was 'Data with No Name. This simple worksheet just gives two datasets from different classes with the information that the data comes from a question asked on the CensusAtSchool questionnaire. The problem set is for them to discover what the data is and what information it contains. Teachers report that this activity encourages learners to explore and examine the data for clues. Encourages them to think of any statistical techniques that they have previously learnt or ways they already know to get information from the data and also to justify their conclusions. Although anecdotal I have received testament from many teachers who have used this activity with their learners. They have told me that they are amazed by how many and what a wide variety of techniques their pupils actually know and given the opportunity to be able to use them to solve the problem presented by this worksheet encourages them to retrieve hidden knowledge and show what they can achieve.



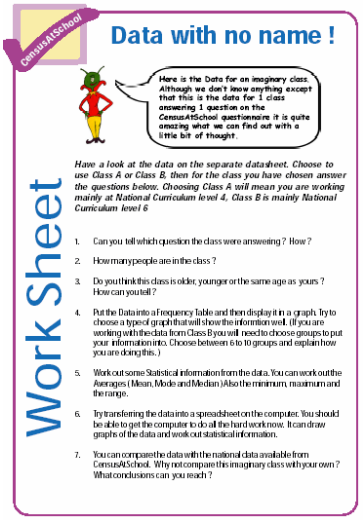
Data Sheet

Class A

148	146	146	149	150
146	145	144	145	146
145	149	153	147	151
147	145	147	153	145
142	147	146	151	145
142	143	148	144	146

Class B

165	178	168	164	167
163	164	184	174	173
161	157	154	166	176
175	182	168	168	160
175	165	164	177	158
181	161	172	166	



Data with no name !

Here is the Data for an imaginary class. Although we don't know anything except that this is the data for 1 class answering 1 question on the CensusAtSchool questionnaire it is quite amazing what we can find out with a little bit of thought.

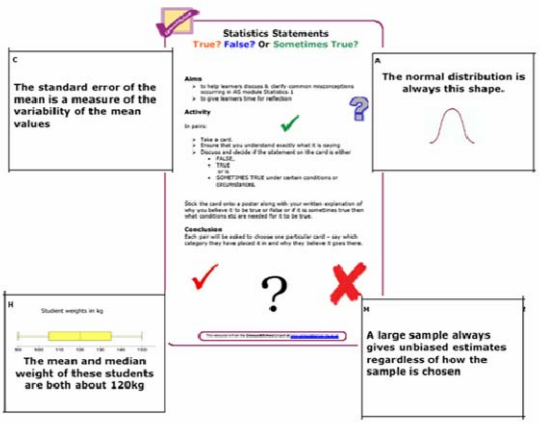
Work Sheet

Have a look at the data on the separate datasheet. Choose to use Class A or Class B, then for the class you have chosen answer the questions below. Choosing Class A will mean you are working mainly at National Curriculum level 4, Class B is mainly National Curriculum level 6

1. Can you tell which question the class were answering ? How ?
2. How many people are in the class ?
3. Do you think this class is older, younger or the same age as yours ? How can you tell ?
4. Put the Data into a Frequency Table and then display it in a graph. Try to choose a type of graph that will show the information well. (If you are working with the data from Class B you will need to choose groups to put your information into. Choose between 6 to 10 groups and explain how you are doing this.)
5. Work out some Statistical information from the data. You can work out the Averages (Mean, Mode and Median) Also the minimum, maximum and the range.
6. Try transferring the data into a spreadsheet on the computer. You should be able to get the computer to do all the hard work now. It can draw graphs of the data and work out statistical information.
7. You can compare the data with the national data available from CensusAtSchool. Why not compare this imaginary class with your own ? What conclusions can you reach ?

Another great example of how this method can really get people to think in a conceptual way is the distributions activity invented by Joan Garfield et al for their "Tools for Teaching and Assessing Statistical Inference" project in 2000. Here learners are given a number of histograms that they have to classify into groups giving justifications for their grouping. Again the discussion and reflection children use when doing this activity helps to embed their conceptual understanding of exactly what a distribution is and why we have different types of them as well as help them to identity different types of distribution in future.

Recently CensusAtSchool has developed several resources inspired by the Swan (2005) mathematical resources fondly called the 'Standards unit box' in the UK. In these activities learners are given a number of statistical statements on cards which they have to discuss in pairs and decide if each statement is 'always true', 'sometimes true', or 'never true'. They are



Statistics Statements

True? False? Or Sometimes True?

The standard error of the mean is a measure of the variability of the mean values

The normal distribution is always this shape.

Aims

Activity

Conclusion

The mean and median weight of these students are both about 120kg

A large sample always gives unbiased estimates regardless of how the sample is chosen

encouraged to develop statistical arguments and justifications, and to devise examples and counterexamples to defend their reasoning. We have developed three sets of these cards at differing levels of understanding relating to our curriculum for 11 to 14 year olds, 14 to 16 year olds and 16 to 18 year olds. Although these have only been recently added to the website we already have had much feedback from teachers saying that the cards really made their learners think about the statistical concepts and also that they themselves were being forced to think in a mush more conceptual way than they often did when teaching statistics.
All of these are examples show how easy it actually is to change the way we teach to focus on the process skills and to empower learners to be able to argue and convince using statistics.

In addition to the process skills, the new UK curriculum also includes new Personal, learning and thinking skills (PLT's). This is forward thinking and aims to help learners secure the basic skills they need for life and work. These skills are organised into 6 groups:

Independent enquirer: who process and evaluate information in their investigations, planning what to do and how to go about it. They take informed and well-reasoned decisions

Creative thinkers: who generate and explore ideas, making original connections, they try different ways to tackle a problem, working with others to find imaginative solutions and outcomes.

Reflective learners: who evaluate their strengths and limitations, setting themselves realistic goals with criteria for success. – is it realistic to use certain techniques regardless of others understanding?

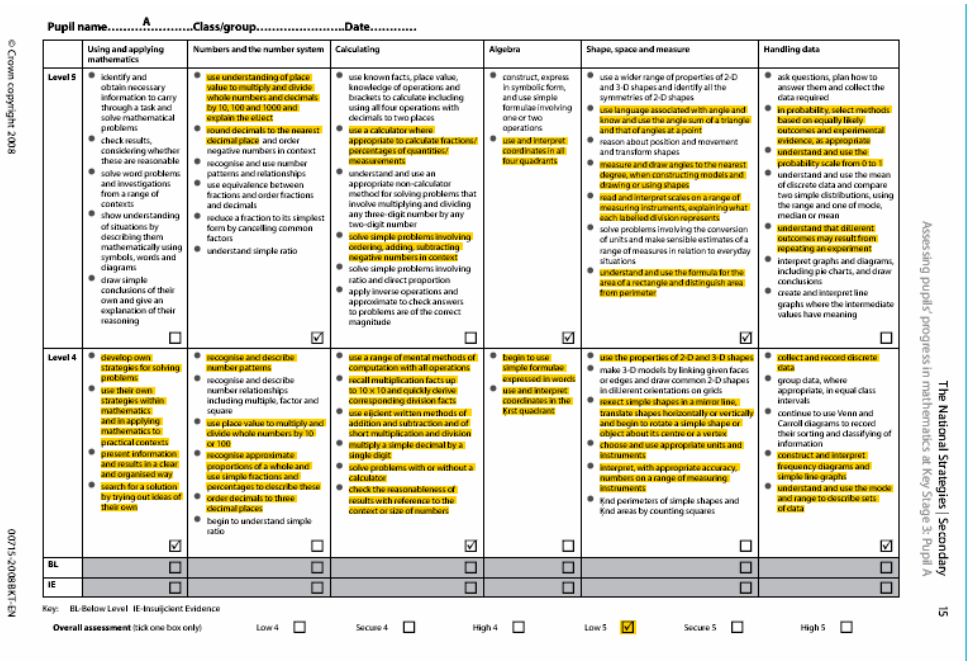
Team workers : who work confidently with others.

Self-managers: who organise themselves, showing personal responsibility, initiative, creativity and enterprise.

Effective participators: who actively engage with issues that affect them and those around them.

As with the process skills we as statistical educators welcome the focus on these very useful skills and can easily see how statistical literacy is a vital component to enable young people to grow and develop in these areas. But it does not fit well with the prescription that we have to do it by using certain named techniques for I see it as unlikely that an Independent enquirer would often choose to use a cumulative frequency graph or use a histogram with unequal class intervals!

A further complication in the UK has been caused by the sudden but welcome demise of the national tests for all 14 year olds after the company responsible for the marking of the papers in 2008 ran into administrative difficulties. Worried that schools might abandon all means of assessment the government have immediately introduced a scheme called Assessing pupils progress (APP) which, for some undetermined reason, relates to the old national curriculum not the new one and offers assessment criteria that teachers are meant to assess every pupil they teach both day-to-day and periodically against. These assessment criteria are very wordy as can be seen



Pupil name.....A.....Class/group.....Date.....

	Using and applying mathematics	Numbers and the number system	Calculating	Algebra	Shape, space and measure	Handling data
Level 5	• identify and obtain necessary information to carry through a task and solve mathematical problems • check results, considering whether these are reasonable • solve word problems and investigations from a range of contexts • show understanding of situations by describing them mathematically using symbols, words and diagrams • draw simple conclusions of their own and give an explanation of their reasoning ☐	• use understanding of place value to multiply and divide whole numbers and decimals by 10, 100 and 1000 and explain the effect • round decimals to the nearest decimal place and order negative numbers in context • recognise and use number patterns and relationships • use equivalence between fractions and order fractions and decimals • reduce a fraction to its simplest form by cancelling common factors • understand simple ratio ☑	• use known facts, place value, knowledge of operations and brackets to calculate including using all four operations with decimals to two places • use a calculator where appropriate to calculate fractions, percentages of quantities, measurements • understand and use an appropriate non-calculator method for solving problems that involve multiplying and dividing any three-digit number by any two-digit number • solve simple problems involving ordering, adding, subtracting negative numbers in context • solve simple problems involving ratio and direct proportion • apply inverse operations and approximate to check answers to problems are of the correct magnitude ☐	• construct, express in symbolic form, and use simple formulae involving one or two operations • use and interpret coordinates in all four quadrants ☑	• use a wider range of properties of 2-D and 3-D shapes and identify all the symmetries of 2-D shapes • use language associated with angle and know and use the angle sum of a triangle and that of angles at a point • reason about position and movement and transform shapes • measure and draw angles to the nearest degree, when constructing models and drawing or using shapes • read and interpret scales on a range of measuring instruments, explaining what each labelled division represents • solve problems involving the conversion of units and make sensible estimates of a range of measures in relation to everyday situations • understand and use the formula for the area of a rectangle and distinguish area from perimeter ☑	• ask questions, plan how to answer them and collect the data required • in probability, select methods based on equally likely outcomes and experimental evidence, as appropriate • understand and use the probability scale from 0 to 1 • understand and use the mean of discrete data and compare two simple distributions, using the range and one of mode, median or mean • understand that different outcomes may result from repeating an experiment • interpret graphs and diagrams, including pie charts, and draw conclusions • create and interpret line graphs where the intermediate values have meaning ☐
Level 4	• develop own strategies for solving problems • use their own strategies within mathematics and in applying mathematics to practical contexts • present information and results in a clear and organised way • search for a solution by trying out ideas of their own ☑	• recognise and describe number patterns • recognise and describe number relationships including multiple, factor and square • use place value to multiply and divide whole numbers by 10 or 100 • recognise approximate proportions of a whole and use simple fractions and percentages to describe these • order decimals to three decimal places • begin to understand simple ratio ☐	• use a range of mental methods of computation with all operations • recall multiplication facts up to 10 × 10 and quickly derive corresponding division facts • use efficient written methods of addition and subtraction and of short multiplication and division • multiply a simple decimal by a single digit • solve problems with or without a calculator • check the reasonableness of results with reference to the context or size of numbers ☑	• begin to use simple formulae expressed in words • use and interpret coordinates in the first quadrant ☐	• use the properties of 2-D and 3-D shapes • make 3-D models by linking given faces or edges and draw common 2-D shapes in different orientations on grids • reflect simple shapes in a mirror line, translate shapes horizontally or vertically and begin to rotate a simple shape or object about its centre or a vertex • choose and use appropriate units and instruments • interpret, with appropriate accuracy, numbers on a range of measuring instruments • find perimeters of simple shapes and find areas by counting squares ☐	• collect and record discrete data • group data, where appropriate, in equal class intervals • continue to use Venn and Carroll diagrams to record their sorting and classifying of information • construct and interpret frequency diagrams and simple line graphs • understand and use the mode and range to describe sets of data ☑
BL	☐	☐	☐	☐	☐	☐
IE	☐	☐	☐	☐	☐	☐

Key: BL-Below Level IE-Insufficient Evidence

Overall assessment (tick one box only) Low 4 ☐ Secure 4 ☐ High 4 ☐ Low 5 ☑ Secure 5 ☐ High 5 ☐

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from the illustration and contain such items as “construct and modify, on paper and using ICT suitable graphical representation to progress an enquiry including frequency polygons and lines of best fit on scatter graphs” and “find the median, quartiles and inter-quartile range for large data sets, including using a cumulative frequency diagram” Teachers are meant to record evidence of this in order to give each child a national curriculum level of attainment. Once again this seems to go heavily against the new curriculum’s primary aim to encourage individuals learners autonomy and encourage them to select the most appropriate mathematics in any situation – here is it obviously as long as that happens to be a cumulative frequency chart! Interestingly in the exemplar material the UK government supply for high ability pupils they resort to using the CensusAtSchool project for the evidence.

“Pupil N takes steps to avoid bias when she has identified possible causes. For example, when comparing the heights of pupils in the UK with South Africa using the Census at School database, she ensured that the age distributions were as wide as possible and were similar for both countries.” The National Strategies (2009)

So it can be seen that the induction of the process skills can be extremely helpful in our push for statistical literacy – governments are starting to realise that in order for their citizens to make forward progress they need to be able to comprehend the world around us and make sense of all of the information available. A recent Ofsted report in the UK found that present strategies are not equipping them well enough mathematically for their futures. “It is of vital importance to shift from a narrow emphasis on disparate skills towards a focus on pupils’ mathematical understanding. Teachers need encouragement to invest in such approaches to teaching.” (Ofsted 2008) then go on to say. “The best teaching was rooted in developing pupils’ understanding of key concepts.” This is reinforced further by Swan (2005) who says “mathematics is something that is ‘done to them’, rather than being a creative, stimulating subject to explore. It has become a collection of isolated procedures and techniques to learn by rote, rather than an interconnected network of interesting and powerful ideas to actively explore, discuss, debate and gradually come to understand.” This is so true of what is happening in statistics classes around the world that it is imperative that we embrace the new process skills and start to really emphasise the process rather than the actual techniques used.

While Ridgway et al (2007) argue that the previous UK national Curriculum provided a very poor basis for understanding of evidence based arguments and was urgently in need of a radical review it is yet to be seen if the new version can overcome the inexorable unmoving temptation to list a load of irrelevant techniques and really do what it purports to aim to do – That is to produce young people who can use the information presented to them in a confident and assertive way to move forward in their understanding of the world they live in. to become the confident aspirational people that all countries wish to produce. We need to realise that the process skills themselves must come first and we must embrace new and inventive ways to interpret data and come to conclusions without the reliance we currently place on tired and over used techniques – many of whom are now out-dated, not useful and in fact hinder our drive forward. The intentions may be good but currently the realities do not match the aims.

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