HELPING MATHEMATICS TEACHERS TEACH STATISTICS: CHALLENGES AND POTENTIALS

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While in many countries Statistics is integrated into the Mathematics Curriculum many mathematics teachers still either view statistics with suspicion or tend to teach statistics in a very mathematical way. Various strategies to overcome these tensions are discussed and activities described and reviewed. Some of the challenges include; how to engage and interest mathematicians in statistics, how to show the differences between techniques and literacy, and how to persuade the teachers that maybe a different pedagogical approach should be taken when teaching statistics as opposed to mathematics. The author firmly believes that many of these challenges can be turned to potentials and that mathematics teachers are the right people to teach statistics in our secondary schools. They just need exposure to suitable activities and time to reflect on the similarities and differences between the subjects considering how to approach the teaching.

BACKGROUND

In statistical circles there is much attention directed to the limited understanding shown towards statistics at all levels of society. It is loudly commented on by many, including Gal (2003), that journalists and the general public have little appreciation of the power or meaning of statistics. They tend to draw incorrect conclusions and use statistics in false contexts which have no meaning at all. My reflection is that this limited understanding is symptomatic of a deeper problem which is how have people come to have that limited understanding and why were they not taught to understand basic statistical concepts at school? The knowledge and concepts that teachers impart to children are surely the building blocks needed to improve the statistical literacy level of the wider population. However when we look at the teachers themselves, and their current practice, we find a picture that is not particularly rosy or encouraging.

In the United Kingdom (UK), Smith (2004) drew attention to the problems of integrating the teaching of statistics within the mathematics curriculum, suggesting that it might be better placed within subjects that make practical use of statistical data such as geography, biology and psychology. The Qualifications and Curriculum Authority (QCA) feasibility study into this idea was carried out by the Royal Statistical Society Centre for Statistical Education (RSSCSE) in 2005 (Davies, Gibson & Marriott 2007) and the results of their national survey clearly shows us that many teachers of these other subjects were more confident than mathematics teachers when teaching learners to understand and interact with statistical concepts and ideas. They reported that the key difference between the approach adopted in geography, science and psychology and that used in mathematics was in the application of statistics to real contexts and problems arising from within each subject. "*Teachers of mathematics were confident in teaching statistical tools or techniques – but teaching students how to use them and when, was more difficult because many of the contexts explored in the mathematics lessons were artificial and manufactured."* This very much reinforces the view of Scheaffer (2006) that mathematics is frequently taught in a deterministic way often focused exclusively on the numbers involved whereas whilst statistics is also about numbers, it is always about numbers in context.

In the USA the position appears very similar with Burrill (2008) reporting that "*with very few exceptions, training for teaching statistics is not part of teacher preparation programs*" her conclusions, as in many other studies, is that when the statistical content is taught as a set of tools or procedures the students do not either learn or retain much statistical knowledge.

Despite the position in a number of countries looking very bleak, evidence from projects such as the CensusAtSchool project I managed and operated for ten years, shows just how simple it can be to engage people in statistical conversations, encouraging connection with both the mathematical/statistical techniques being used and the social argument about the inference and meaning in the data. To try to illustrate this I shall use a single example taken from

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CensusAtSchool. The graph being used (see Figure 1) depicts the average heights of children from the UK, South Africa and Queensland with the data coming from the 2001 pilot of CensusAtSchool. Firstly the audience are shown the graph with just the UK data of girls and boys average height for ages between 8 and 18 years. This leads to debate about why the gender differences (clearly seen on the graph) occur. Then the audience are asked where a graph of South African children's heights will be positioned. Social debate ensues, often centred on differences between cultures and if being in the northern or southern hemispheres will cause variation in the data. The South African graph is then displayed and debate continues about the similarities in the gender pattern. Finally the audience is asked where they expect the Queensland children's height data graph will be positioned and responses collected. The Queensland graph is then shown. This always causes a pause as people reflect and take in the obvious variation in the girl's data. "Do girls in Queensland shrink when they get to 16?" is often the question asked, accompanied with laughter, as the audience seeks to make sense of the graph they are seeing. They always want to know why the graph is shaped as it is. The explanation for this is that it is an error by the graph's creator who failed to properly stratify the groupings used. The reason for the shape of the graph is that, among the many thousands of children the graph portrays, only 4 of the Queensland girls were actually 16 and they happened to be a little shorter than average. This always leads the conversation right back to the mathematical technique used to create the graph. It quickly leads to debate about the rights or wrongs of using a line graph at all, even when the data is showing many thousands of children.

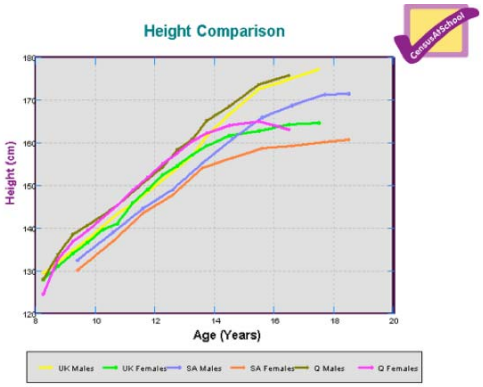

Figure 1. Average height Comparison

This one example shows how important the connections between the techniques being used and the interpretation of the data are and how a simple example can easily clarify why both of these things are important for everyone to understand. This one example causes people to think about the close interactions between mathematics and statistics and indeed about the disparity in the statistical interpretation of a graph and the mathematical techniques used to create it.

THE SESSIONS

So how can the current position be improved? In the UK trainee teachers on Post Graduate Certificate in Education (PGCE) courses are in University for just 12 weeks of their 40 week courses and have only around 160 hours of direct input during their entire training. For potential secondary mathematics teachers the actual subject content of statistics is often never even mentioned or perhaps an hour or two is given over to its study. This is despite a situation where potential mathematics teachers may not have studied statistics at all in their final years at secondary school or at undergraduate degree level. So if there is a couple of hours given to the consideration of the teaching of statistics how should this valuable time be spent? Biggs and Tang (2007) say that *'Effective teaching involves getting students to agree that appropriate task engagement is a good and impelling idea (otherwise known as motivation) and establishing the kind of climate that will optimise appropriate interactions.'* This is my primary aim with these sessions.

Especially with trainee teachers although less so with in-service courses, the session with me is the only contact they have with the subject matter of statistics. I try to focus on the experiences they need in order to be able to teach statistical literacy effectively to their pupils. As has been commented on by many distinguished statisticians the disciplines of mathematics and

statistics often pull in very different directions. Whilst much of mathematics is deductive and focusing on one correct answer statistics can often end up with more questions than answers and looking very messy and unfinished. My belief is that this focus on a variety of outcomes is crucial to statistical thinking. So I need to give the participants a feel for this whilst also offering a wide variety of suitable resources for them to take into their classrooms. I was very mindful that research such as Skemp (2006) Ball (1988) and Schoenfield (1983) which shows us that many prospective teachers tend to "teach as they were taught" and that the critical influence on teachers about pedagogical decisions often come from their own background so it is important to ensure that this position is challenged during the session whilst alternatives are offered.

To begin the session I use material from a number of sources. Some marvellous scenarios from the media are presented by Blastland and Dilnot (2007) in their book "The Tiger that Isn't" By putting some of the headlines up and asking the question that Blastland suggests in the book – Is that a big number? Students soon start discussing the background behind the figures – *Where did they come from? – How many people are they shared out between?, What question was actually asked*?, *How many people were asked?, What were the other factors behind the situation from which the headline figure was constructed?*. Following a few of these scenarios I put up a picture of 3 sheep with the question *How Many?* (again an example used in Blastland & Dilnot's book) And I continue to find it fascinating how the audience – whether is it trainees , experienced teachers, or mathematical educators lapse into silence (or a few nervous giggles) and very rarely does anyone venture the answer - 3! Just by presenting a few simple cases where figures have been massaged or presented in a particular way people are now doubting what is obviously before their eyes. They are starting to think statistically!! Often, after a few seconds, suggestions will be made (as predicted in the book) that one might be a lamb so only half a sheep or one might be pregnant and counts as one and a half, or the perspective of the picture means they might all have differing values. Once they start reflecting along these lines the audience can become really creative and enjoy thinking up more and more possibilities. In this atmosphere it is very easy to move to the discussion of how statistics and mathematics can involve differing thinking processes. Using further examples from research done by Watson (2005) enables the discussion to deepen into how children perceive the numbers and statistics they are given and also how children can work really hard to try to give the answer they believe the teacher wants from them, rather than attempt to gain real mathematical or statistical understanding of a situation.

The next part of the session is to involve the trainee teachers in a variety of activities designed to get them discussing and reflecting on statistical situations (Figure 2). Here I use a number of resources I have developed for CensusAtSchool which have been very strongly influenced by Malcolm Swan's research and work on improving learning within mathematics lessons. His approach is summed up by the following quote *"Our aim is to make mathematics teaching more effective by challenging learners to become more active participants. We want them to engage in discussing and explaining their ideas, challenging and teaching one another, creating and solving each other's questions and working collaboratively to share their results. They not only improve in their mathematics; they also become more confident and effective learners."* (Swan 2005). I wish to attempt to do the same but with the content being more statistical in nature.

Figure 2. Discussion Activity

The activities include: Statistics Statements: True? False? or Sometimes true? (This comes in three versions aimed at differing age and ability groups and related to the subject matter in the

UK national curriculum (see Figure 3), Distribution Shapes–adapted from the Distributions activity devised by Garfield et al. (2000) in their tools for teaching and assessing statistical inference, How Old? (Resource from CensusAtSchool) and an activity called Frogs. (Resource from CensusAtSchool). Along with these I also use several of the 'Improving Learning in Mathematics' standards unit activities (Swan, 2005) which are focused on matching up varying types of graph, statistic and description.

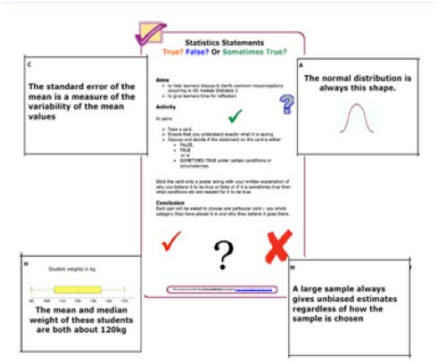

Figure 3. Statistics Statements

The session usually finishes with a discussion about the session itself and asks the teachers how they feel about both the content and the approaches used. Do they feel that they will try out some of the activities in their own classrooms and if so which and why? Do they feel that they have a better appreciation of what the whole point of teaching statistics is? Has the session moved them forward in their own personal understanding of any statistical concepts?

SESSION OUTCOMES

These sessions put the teachers into the role of learners and by doing so they quickly discover for themselves both the pedagogical advantage of the inclusion of discussion and negotiation in activities and at the same time are able to move forward their own understanding of the statistical concepts involved. Every time I have engaged either trainee or practising teachers in these activities I have been intrigued by the way that they improve their own levels of knowledge about the statistical concepts involved at the same time as reflecting on the advantages of using this type of task or activity. It is inevitable that common mistakes and misconceptions are exposed and those participants with a greater level of understanding can quickly help those struggling with their own knowledge level. On many occasions when I have had the opportunity to talk to individual participants following these sessions they reflect both on how far they have moved forward in their own levels of understanding of the statistical concepts involved, and that this has been achieved in a very non- threatening and positive way. They quickly see how the various statistical concepts are linked to each other and how understanding of one concept can lead quickly to understanding of others. This approach also confronts the mathematicians' usual way of doing things which is often to teach each technique in isolation and easily injects the idea that the linkage and connections between the various techniques is actually extremely important. For example to be able to match up a frequency graph with its cumulative frequency graph with its box and whisker plot and with a statement describing the context requires a very different level of understanding that simply having to construct or produce a cumulative frequency curve or a box and whisker plot. In the card matching activities the focus is on the interpretation and by using multiple representations of the same situation each individual can use the concept they have the most understanding of to ensure correct interpretation.

CONCLUSIONS

Although the ideas I have put forward in this paper are very simple, I feel that they offer an effective way to get mathematicians to consider and question their own established way of 'Doing Mathematics (including statistics)' and to consider different pedagogical approaches while at the same time they enable the teachers to become learners and move forward in their own understanding of statistical concepts.

There are many ways to take these approaches further. In the matching cards activity by including blank cards for the participants to fill in themselves or hint cards for those facing difficulties an element of differentiation can easily be incorporated. Participants can also be encouraged to invent their own example/s and this can reinforce the concepts learnt and offer both support and challenge. These types of activity can stimulate statistical thought and encourage movement beyond routines and outcomes, to ask questions and to search for the reasons as to why.

I firmly believe that statistics should be based on this type of problem solving approach and an element of discussion and collaboration should be built into all teaching and learning activities. The only way to encourage a higher level of statistical literacy among both our learners and their teachers is to offer simple and straightforward ways to allow the teachers to move themselves forward in their understanding themselves. As Gelman and Nolan (2002) say following a first unsuccessful statistics course which they felt on analysis was too focused on content and not enough on skills: *"Watching the teacher tell you a solution or solve a problem… is not as effective or satisfying … as actively involving themselves (the students) in problems."* And this I would endorse. Any attempt to try and tell mathematics teachers outright that they are not teaching the statistics part of their syllabus well enough is unlikely to be greeted with enthusiasm! By using the methodology described above the teachers make that discovery for themselves and by using the varied pedagogy encourages them to try out this type of activity in their own classrooms where they are free to assess the impact themselves on the learning their pupils achieve. Teaching and learning are very closely related activities with much in common and if we are to find ways to help our mathematics teachers teach the statistical content of their courses in a way more closely aligned to the consensus of current statistical education research then we must find useful and practical ways to move forward on this. If you are interested in using any of the activities described above in your own teaching then do please get in contact with the author. To finish with a quote from Scheaffer (2006):

> *"Mathematics and Statistics follow two quite different paths of reasoning. If these paths are made clear they can complement each other in ways that will strengthen both – and make students the winners all around."*

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