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Triumphs and Tribulations in Teaching

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Good morning and thank you for coming to listen to my Presidential Address. You have been listening to Meat Loaf's *Bat out of Hell* and for those of you who are used to seeing me in various costumes I apologise for not appearing as Batman on a Batbike, but I know my limits (like $\lim_{n\to\infty}\left(1+\frac{1}{n}\right)^n = e$).

The illustration on the front cover of the *Gazette* is a bit of a turkey. It comes from an old mathematics exercise book by Henry Smith who started it in 1843 and appears just before he does some examples on the single rule of three direct in vulgar fractions. I wonder how long it took him to do it, but there has surely been some implicit mathematics done in managing to get the wording arranged fairly equally around a circle! The rest of the exercise book is very neatly presented and illustrated, though without any indication that the work has been marked in a summative or formative way. Hence it would not meet today's standards.

It has been a great privilege and a delightful pleasure to serve The Mathematical Association and the mathematical community as President over the past year. I am the 102nd President: the first one to use three different digits. This inspired me to give you a simple starter in the form of two Kenken puzzles. (I like the title because Ken is my brother and he is one of my inspirations: for a while he had his own league table of schools in the north west as he trained as an electrical engineer and did some work on security systems. His league table was based on how he was greeted at a school: whether he was offered refreshments and treated as a member of the human race or as an inferior species.) A Kenken puzzle is basically a Latin square where, in this case, each row and column contains the digits 0, 1 and 2 and the cells in the black borders give the result shown using that operation.

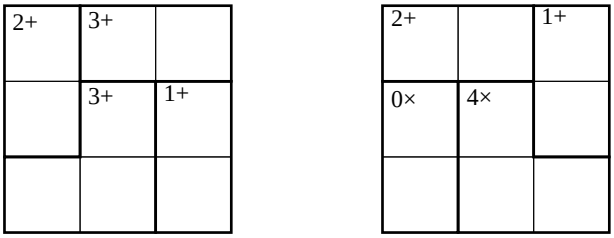

FIGURE 1: Two puzzles based on 1, 0, and 2

Now those of you who have come expecting me to talk for the whole session while you listen (or doze) will be sorely disappointed. After 30+ years of teaching in state secondary schools I realise that talking for an hour is a recipe for disaster so I will be inviting you to do some (mathematical)

work at various points.

Your first bit is rather pointless. In early April the first number question appeared on Pointless: the TV show where contestants have to find the least popular answer. These were the statements (plus answers) and the contestants had to correctly provide the answer that they thought would be the least well-known:

Number of degrees in a circle	360
Number of minutes in a FIFA football match without added or extra time	90
Number of shillings in a pre-decimal sterling pound	20
Number of bones in the normal adult body	206
Number of millilitres in a litre	1000
Number of pairs of chromosomes in a human body cell	23
Number of seconds in an hour	3600

Now, how many of the 100 audience members do you think got the mathematical questions correct? Here are the results in order of popularity:

Number of degrees in a circle	85
Number of minutes in a FIFA football match without added or extra time	74
Number of millilitres in a litre	73
Number of shillings in a pre-decimal sterling pound	44
Number of seconds in an hour	42
Number of pairs of chromosomes in a human body cell	13
Number of bones in the normal adult body	6

Not quite as scientific as TIMSS or PISA, but at least it shows that there is some recall of mathematical facts.

I started teaching in September 1977 after doing my PGCE under Mike Cornelius at Durham University and it is good to see some other protégées of his here in the audience. Doing the PGCE meant it postponed making a decision on how I would make a living for a year and also meant I would be doing the course with my new wife Janet as she decided to teach French (and Italian and Latin). Little did she know that mathematics was my mistress! The mathematical world owes her a great debt as she has made many sacrifices to allow me the time to spend on mathematics. Now I do some part-time work on the PGCE course at Bath Spa University amongst other work and it is fascinating to see how things have changed over the years, some for better, some for worse.

Here are three things that bring joy to my heart.

1. Seeing the enthusiasm of people new to teaching: they are willing to trial methods new to them and have boundless energy. I have seen some mathematics departments invigorated by their infectious enthusiasm. They spend time planning thoughtful lessons that show differentiation, Assessment for Learning (AfL) and they reflect on their lessons and are always looking for evidence of pupil progress.

2. Talking with mentors and staff whose classes are being taken. These are just some of the teachers who 'go the extra mile'. We are a caring profession and I have seen student teachers flourish under their mentor's guidance. A friendly arm round the shoulders goes a long way to help when a lesson has not gone exactly as planned!
3. Seeing how positive teachers can be: I reckon that if I poured every teacher's glass into a giant container it would be well more than half full (and perhaps even overflowing).

But that is enough talk: let us now do some more mathematics and develop your mental geometry. I have to thank Lord Winston for his input yesterday and he mentioned neural connections and synapses, which is relevant to what will happen in your brains when you try this activity. Mental geometry is a neglected part of all school mathematics. To encourage pupils to develop their mental geometrical skills I show them a simple figure based on a 5 by 5 square array of dots, drawn large enough for the whole class to see. This is then given a half turn so that the class now sees the back of the board. They then have to draw exactly what I can see. Students draw the result on a piece of dotty paper. After they have drawn their attempt, I turn round so that they can see the result.

Initial success with this task is rare − as some of you will have experienced! However repeating this every half term or so soon sees increasing success with mental geometry and students need to appreciate that since we live in a 3D world things can appear differently depending on our viewpoint. The repetition strengthens the synapses and hence makes it easier to visualise the end result.

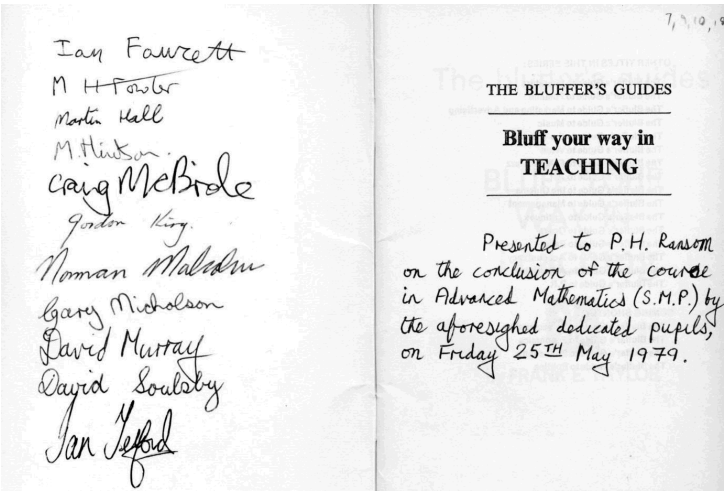

FIGURE 2: Bluff your way in Teaching

Now let us consider (C)PD on how it has developed over the years and the parts played by our organisations. When I started teaching at Houghton-le-Spring in the Borough of Sunderland I was given a group of 11 lower sixth pupils to take through SMP A level Mathematics. On 25th May 1979 when they left they gave me the book 'Bluff your way in Teaching'. Most of the advice it contains is as good today as it was when this copy was printed in 1974 − 40 years ago.

FIGURE 3: David Murray presenting to Peter Ransom in 1979

'New and revolutionary teaching methods are constantly being thrown up. Not often by teachers, who are far too busy in the classroom, but by others who see their ratings in the educational charts slipping and need to claim the public eye. These methods normally have but a brief life and are seldom adopted in depth, so don't bother with lengthy courses of instruction. However, it is as well to know what they are all about − the elements are quickly assimilated along with the relevant vocabulary. Used while the method is enjoying its brief vogue, it gives a pleasing up-to-date impression.'

My head of mathematics, Steve Feather, encouraged me to go on courses and in my first year I attended one by David Burghes on Mathematical Modelling and learnt about how James Berry, the Victorian hangman, modelled the drop needed to break the neck and not strangle or decapitate the condemned.

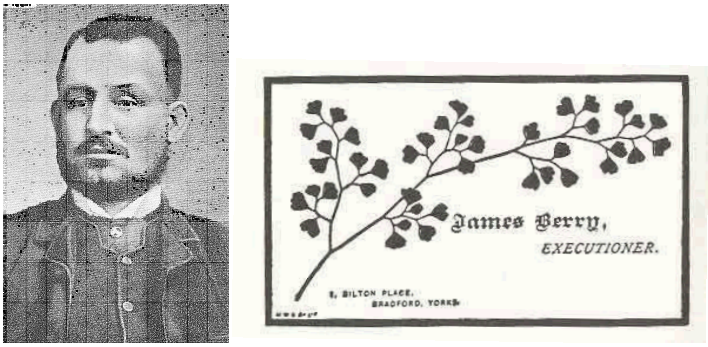

FIGURE 4: James Berry and his calling card

This inspired me to produce a model gallows which I used for a number of years, though I have not used this with classes for quite a while. I have brought it along today to demonstrate to you the effect of a drop too long and one too short. James Barr, M.D., reckoned that the weight of the criminal multiplied by the length of the drop should range from 1120 to 1260 foot pounds to dislocate the cervical vertebrae between the atlas and the axis (first and second vertebrae).

How does this fit with Berry's revised model below?

SCALE SHOWING THE STRIKING FORCE OF FALLING BODIES AT DIFFERENT DISTANCES.

Distance Falling in Feet	8 Stone	9 Stone	10 Stone	11 Stone	12 Stone	13 Stone	14 Stone	15 Stone	16 Stone	17 Stone	18 Stone	19 Stone
Zero	Cw. Qr. lb.	Cw. Qr. lb.	Cw. Qr. lb.	Cw. Qr. lb.	Cw. Qr. lb.	Cw. Qr. lb.	Cw. Qr. lb.	Cw. Qr. lb.	Cw. Qr. lb.	Cw. Qr. lb.	Cw. Qr. lb.	Cw. Qr. lb.
1 Ft.	8 0 0	9 0 0	10 0 0	11 0 0	12 0 0	13 0 0	14 0 0	15 0 0	16 0 0	17 0 0	18 0 0	19 0 0
2 „	11 1 15	12 2 23	14 0 14	15 2 4	16 3 22	18 1 12	19 3 2	21 0 21	22 2 11	24 0 1	25 1 19	26 3 9
3 „	13 3 16	15 2 25	17 1 14	19 0 12	20 3 21	22 2 9	24 1 8	26 0 7	27 3 5	29 2 4	31 1 2	33 0 1
4 „	16 0 0	18 0 0	20 0 0	22 0 0	24 0 0	26 0 0	28 0 0	30 0 0	32 0 0	34 0 0	36 0 0	40 0 0
5 „	17 2 11	19 3 5	22 0 0	24 0 22	26 1 16	28 2 11	30 3 5	33 0 0	35 0 22	37 0 16	39 2 11	42 3 25
6 „	19 2 11	22 0 5	24 2 0	26 3 22	29 1 18	31 3 11	34 1 5	36 3 0	39 0 22	41 2 16	44 0 11	46 2 5
7 „	21 0 22	23 3 11	26 2 0	29 0 16	31 3 5	34 1 22	37 0 11	39 3 0	42 1 16	45 0 5	47 2 22	50 1 11
8 „	22 2 22	25 2 4	28 1 14	31 0 23	34 0 5	36 3 15	39 2 25	42 2 7	45 1 16	48 0 26	51 0 8	53 3 18
9 „	24 0 11	27 0 12	30 0 14	33 0 23	36 0 16	39 0 18	42 0 19	45 0 21	48 0 22	51 0 23	54 0 25	57 0 26
10 „	25 1 5	28 1 23	31 2 14	34 3 4	37 3 22	41 0 12	44 1 2	47 1 21	50 2 11	53 3 1	56 3 19	60 0 9

FIGURE 5: Table giving the strike force for a given mass and drop in imperial units

I found all the examples very interesting and decided that these case studies would always be included in what I taught.

The following year I did a course led by Hugh Neill on teaching SMP Further Mathematics as I was due to teach that the year after. This was a couple of hours after school every fortnight and that helped me considerably in understanding what I was expected to teach.

In January 1980 I joined both The Mathematical Association and Association of Teachers of Mathematics and started attending meetings of the North East Branch of The Mathematical Association every month (at the time there was no ATM branch in the area). Since there was little or no school-based PD teachers got it where they could and the association seemed to flourish. If you have not been to a branch meeting then go along and experience them − it is mathematics-specific CPD just as is recommended in the Ofsted *Understanding the Score* report.

- Key findings: In the more effective schools, collaboration between staff supported their professional development but, generally, opportunities for teachers to improve their subject knowledge and subject-specific pedagogy were infrequent.
- Schools should: provide well-targeted professional development in mathematics, particularly to improve teachers' subject-specific pedagogy and the subject knowledge of non-specialist teachers of mathematics.

Show this report to the senior leadership in your school and fight for mathematics-specific CPD, not the generic mishmash that is sometimes served up based on recent fads that do not necessarily have sound scientific research to back it. CPD is the oxygen that keeps mathematics teaching alive and the recent (November 2013) ACME report *Empowering teachers: success for learners* makes far-reaching recommendations. I hope that senior leaders read this document and act on it. At the London Mathematical Society I have been working on a new grants scheme to provide small grants to help mathematics teachers attend CPD and for non-commercial concerns to set up some CPD themselves − this should be available at some point this year. Keep a look-out at

http://www.lms.ac.uk/grants/small-grants-education

Engaging your audience is essential. Sometimes it is very hard to find out what makes pupils ‘tick’ (or cross!). One pupil of mine in the late 80s didn't seem interested in mathematics at all: he knew what he was going to do at 16 when he left school and was already probably making as much money as I was at the time. His interest was in tractors. He would buy old tractors at auction, fix them up then sell them on, always keeping some for himself as he would use them to do some large scale gardening for people in the vicinity. Once I found this out there were always one or two tractor oriented questions: circumference of tractor wheels, capacity of odd-shaped diesel tanks, how long to plough a field etc. More recently one pupil who rarely settled came on board when I appeared in 1940s RAF uniform and did some work on the geometry of the Dambusters. He was interested in the badges on the uniform, the medal ribbons and the mathematics we were doing as he was in the ATC and had done some similar work on bearings there. I have done many lessons and masterclasses in period costume − linking in the mathematics with history and how it is used makes connections for some (most? all?) pupils on why we study mathematics.

I have often had comments from teachers on how is it possible to pack such activities into an over-crowded scheme of work. I have no magic formula for this − it just seems to work and I have written some papers about these episodes. I believe that by providing a rich environment for mathematics it makes it easier for pupils to remember so when it comes to book-work they need less time there. I have no concrete evidence for this but I do know that the results in mathematics where I taught were very rarely queried and were always on an upward trend.

- 1999 Cross-curricular work involving mathematics using hand-held technology
- 2001 ICT and Mathematics: a guide to learning and teaching mathematics 11-19
- 2002 John Blagrave (sundials with software)
- 2003 Developing Geometrical Reasoning in the Secondary School (joint paper)
- 2008 Working with Gifted and Talented learners
- 2011 A cross-curricular approach using history in the mathematics classroom with students aged 11-16
- 2012 Cross-curricular STEM work with 11-18 year old students using hand-held technology

FIGURE 6: Some research papers by the author

Pupils like making things and taking them home to show parents. It is not often that we do this in mathematics, but one item that pupils make with me is a set of proportional dividers. These are fairly simple to make and the mathematics behind them combines both geometry and ratio. A full description appears in *SYMmetryplus* 50 Spring 2013.

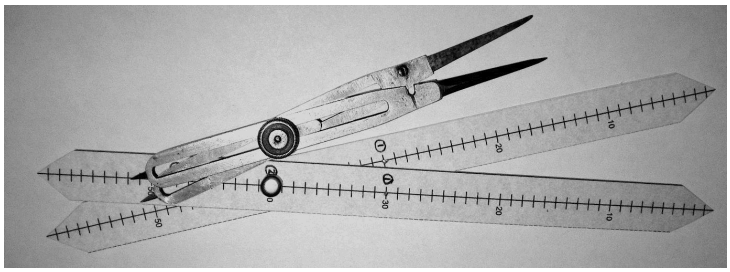

FIGURE 7: Proportional dividers in metal and card

This old mathematical instrument would have been part and parcel of the toolkit of an architect, engineer or artist and they were also part of a mathematical instrument set. I even have a suspicion that it may not be banned from use in public examinations! Pupils experience success in making this as the central scale is not harmed when the card is cut out, so provided the paper fastener is carefully inserted, it works remarkably well when enlarging lines.

Technology − love it or loathe it, it is here to stay. Used well it can be a

boon to teaching and learning. My first use was an LED di(c)e my brother made for me − I am still not sure why I used it when I could use real dice: perhaps it was because it was noiseless. Then there was the PET. I hate to think how many hours I spent trying to program the machine and save programs on magnetic tape. This was followed by the ZX81 for which my brother made something that could link it up to a large black and white TV in my room − the electronics fitted inside a tobacco tin (I smoked a pipe at the time, so there were always plenty of empty tins for storage). Since the 90s I stuck with Texas Instruments graphing calculators and then switched to using their hand-held wireless technology as this helped greatly with AfL as I could see what everyone was doing and how the lesson was proceeding.

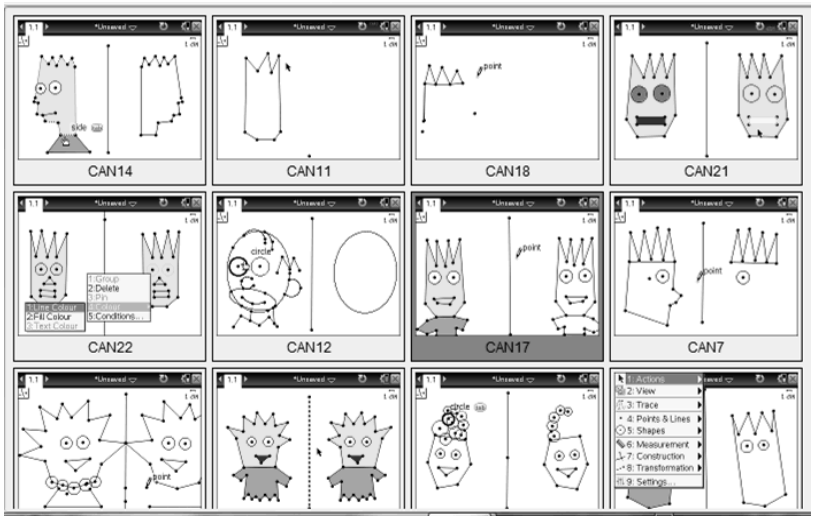

FIGURE 8: Screenshots from a lesson on reflection

The picture above comes from a session on exploring reflection with PGCE students at Canterbury Christ Church University this year. They had no previous experience of this technology yet found they could manage the menu system very quickly. I have found that when working with pupils they cope with the technology far more quickly than their teachers imagine and are motivated by opportunities that allow them to be creative.

But why are we using (or not using) all this technology? Last year the *Times Educational Supplement* ran an issue on the use of technology and here are two questions that make me think.

Will spending a fortune alter the nature of learning? Will we as teachers be made redundant?

In my opinion the answer to both of these is NO! Learning is a dialogue that technology can aid, but not replace. It is not a substitute for good teaching and I hope that you will continue to use your judgement on the best way to teach your students. I have used technology when I felt it was

appropriate and added something to the teaching and/or learning of those concerned. Reflecting on your lessons is a major part of improving one's work.

The MA and ATM have given me hundreds of ideas throughout the past four decades from twilight sessions, one-day conferences, annual conferences and correspondence with mathematicians over the globe. I have attended an ICME every four years since 1988 and recommend that every mathematics teacher should participate in an annual conference every two years and at least one ICME every decade. You get even more out of these conferences if you do a session! Ask for financial help with these: annual conferences take place during vacation time so there should be no demand on cover for your school and you will be using the benefits with your pupils so schools should be paying for this − after all you are giving up your time. With the grants scheme mentioned earlier you should not be out of pocket!

Tribulations − changing curriculum and Ofsted come immediately to mind. We have seen many consultations over the past few years and the number of hours spent on these must be incredible. Hopefully we will see an improved curriculum emerge and some excellent impartial advice to accompany it. It might not be to every individual's choice, but when two people are involved in discussion there are at least three different opinions (so they say). I am aware of Tony Gardiner's work in producing 'Teaching Mathematics at Secondary Level' that should appear soon on the De Morgan Gazette:

http://education.lms.ac.uk/the-journal/

This has grown out of work from Tony and has many contributions from others. It is not a manual on how to teach, but clarifies certain crucial features of elementary mathematics and how it is learnt. All school mathematics departments should bear this document in mind when choosing their approach, thinking about long-term objectives and reflecting on observed outcomes. I have no reservations in recommending this to every mathematics teacher.

It will be interesting to see what emerges with the new GCSEs. It is always a tribulation when examinations change as schools have fewer resources initially though mathematics itself does not change. My advice is to continue what you do well − teach enthusiastically and your pupils will do their best.

I have seen many pupils triumph with successes in the UKMT challenges. These mathematical challenges get pupils thinking about their mathematics and applying it. There are individual and team events and I have been involved for many years right from the start when the MA decided to do its own national mathematics challenges rather than use the American one. Based at the University of Birmingham these took off and then the UKMT was formed. I would love to see the day when GCSE questions become more like these challenge questions. It never ceases to amaze me that our examination system is still an individual event with no IT

allowed. We are still rooted in the 19th century as far as examinations go. No workforce operates in such a way. Mathematicians use technology and communicate with each other to solve problems. People work in teams rather than as individuals so why are we testing pupils in such an alien way? Perhaps it is no wonder that industry decries the skills with which pupils leave schools as so much importance is placed on examination success. Hence the STEM agenda is so very important.

I would like to see more teachers taking risks with their teaching: try something new, something that interests you. Do some research, write articles for our journals letting us know what you find. Now, a final experiment with a large audience. This bottle of wine will go to the person who selects the lowest positive integer that nobody else chooses. Make your decision, write it down and show it to someone nearby so that there is no cheating! (It was won by the number 4.)

To sum up: it has been a very tough few years for teachers − we have seen people leave the profession but there are still people wanting to become mathematics teachers. Unfortunately it will be a long time before the estimated 5,500 shortfall is made good. In the past few years I have worked with many PGCE students, NQTs (through the Prince's Teaching Institute) and more experienced teachers. I believe the future of mathematical education in the UK is safe in the hands of these enthusiastic experts. It is fantastic to be here with so many people sharing their experiences from all our associations, organisations and learned societies. I look forward to speaking with many of you during this congress. Thank you for your time this morning in listening to me. May the MA be with you.

By the way, in case you were wondering how fast a bat out of hell is, noctule bats fly at about 30 mph (50kph).

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