A Shortage of Mathematics Teachers: What Can be Done?

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1. Introduction

In a landscape where there are already too few teachers of mathematics, the recently introduced new post-16 Core Maths qualification will place a greater demand on the already limited supply. Acknowledging that there are simply too few mathematics teachers, the current government is investing significantly and a major plank of the Government's current plan, to improve mathematics instruction, is the Teacher Subject Specialism Training (TSST) programme. Can this provide a sustainable way of helping the nation to improve its mathematical provision at a time when economically competing countries, particularly in the Far East, are making significant improvements in their mathematical standing in the world?

2. What is effective mathematics teaching?

For the purposes of this paper we need to have an agreed 'understanding' of what is 'effective' mathematics teaching; until we know what *is* effective teaching, we won't know when we have '*it*', nor how to go about getting more of '*it*'. Much research surrounds the above question - often with the explicit intention of defining an 'effective teacher'; an agreed definition of which, remains elusive. The recent report by Coe, Aloisi, Higgins, & Major (2014) for the Sutton Trust explores 'What makes great teaching?' and acknowledges that defining 'effective teaching' is no easy task. The definition settled upon in their report is: "We define effective teaching as that which leads to improved student achievement using outcomes that matter to their future success" (2014, p.2). This definition, is the one settled upon by the National College for Teaching & Leadership (NCTL), for their aspirational outcomes from the TSST programme. But it does provoke further questions: What outcomes matter and what do we mean by 'future success'?

There are a number of studies that connect the teachers' understanding of the mathematics they are teaching with the efficacy with which students learn it. This does seem intuitively reasonable. Hill et al (2005) explored the significance of teachers' pedagogical content knowledge in mathematics: high scoring teachers (on their Content Knowledge for Teaching (CKT)) were "associated with more than a month's additional learning for students in a year. Although this is not a huge effect, it is of similar order to the strength of the relationship between socioeconomic background and attainment". The difference Coe et al (2014) found was mostly between the 'lowest scoring teachers and the rest'; this may suggest that a real difference could be made by concentrating professional development opportunities on those mathematics teachers scoring amongst the lowest 20%; “once their CKT School was into the third decile there was no further relationship with the student learning” (Coe et al, 2014).

Ball and Bass (2000, p.95) believe: “It is not just what mathematics teachers know, but how they know it and what they are able to mobilise mathematically in the course of teaching… it is this pedagogically functional mathematical knowledge that seems to be central to effective teaching…” Pedagogical Content Knowledge (PCK) is now a well used phrase but was first coined by Schulman (1986) to describe the teacher knowledge that links content and pedagogy and the interweaving of the two.

The McKinsey report (2007), based on effective educational systems from around the world, makes it clear that subject knowledge is important but that teachers also need to observe and reflect and identify what makes for great instruction in their subject and then have in place support in schools to ensure that teachers can deliver great instruction lesson after lesson; that is, provide an environment that sustains great instruction.

Of course teacher expertise is defined in terms of cultural expectations as Li and Kaiser (2011) point out: “Different countries have different assumptions about what it means to have expertise in mathematics instruction…there is no single definition of teaching expertise…” It is interesting and perhaps revealing to compare the Western attitude to achieving in mathematics with that of our Eastern counterparts: ‘aptitude’ versus ‘effort’, perhaps. We, most notably in the UK and in the USA, often labour under the shared cultural belief that only the few will ever be any good at maths, so we set out to find and cultivate those few, by sifting, sorting, setting and streaming. In direct contrast to this, Askew et al (1997) discovered that highly effective practitioners ***believe*** that ‘almost all pupils are able to become numerate’. The fact that, in spite of our deeply ingrained cultural belief, highly effective practitioners *still* believe ‘almost all pupils are able to become numerate’ may be a powerful and significant one. And it may be our collective lack of this belief which hobbles us as a country. Mathematically successful countries, such as Finland and Japan, fundamentally believe that almost all students can achieve in the subject.

In the Far East - effort and diligence are expected for mathematical mastery. In the West we generally believe only some are, and can be, mathematically ‘gifted and talented’. Perhaps confirming the East’s notion of mathematics, Brian Cox (in a newspaper interview, 2014) said: “When most people say I can’t do maths what they mean is they can’t be bothered. You can actually if you want to. Mathematics is mainly about application and practice.”

The UK government is now appealing for more ‘grit’ and determination from our students. I would argue that whilst it remains a widely held belief that only a few can ever be any good at mathematics, it is going to be an uphill struggle to persuade our students to apply themselves more. This, combined with our culture of ‘hoop jumping’ tests, does not lend itself to perseverance and tenacity. Could the new post-16 Core Maths qualification buck the trend and encourage a more robust response from our students? And could this trigger a trickle down affect into Key Stage 4 and Key Stage 3 mathematics teaching?

The international evidence suggests teaching by ‘problem solving’ is a key strategy to drive deeper understanding and learning, and ‘problem solving’ is set to be the principle teaching strategy for the new Core Maths qualification. The *problem* with ‘problem solving’ is it can sometimes be tricky to define and it is certainly a problem to assess. Problem solving can also mean different things to different people. Two versions of teaching by ‘problem solving’, commonly referred to, are:

- **Guided rediscovery**: A mathematics problem is set to drive the learning. Students don’t know ‘something’ and a problem is set to drive them from where they are to where they need to go.

- **Complex situation:** A problem is set where the mathematics required may already be known but the situation is which it is sited is complex.

Teaching effectively by ‘problem solving’ is a highly skilled activity and requires teachers to:

- be able to clearly articulate - to themselves - what it is they want students to understand;
- recognise that selecting the ‘problem’ is key. Ideally the ‘problem’ should have multiple entry points and multiple solution paths - to allow the ‘problem’ to be accessible to all (i.e. low floor, high ceiling);
- acknowledge the ‘problem’ should pique the students’ curiosity so they are provoked to pose their own questions;
- be able to carefully orchestrate the discourse to guide students to the goal of understanding, i.e. ‘guided rediscovery’.

In Japan, mathematics teachers are described according to three levels of competency (Sugiyama, 2008 cited in the APEC guide: Guide for Planning and Analyzing Mathematics Lessons in Lesson Study). The teacher expertise required to successfully deliver purposeful ‘problem solving’ may need to be of Level 3 type competency, as described by Japanese educators:

Level 1: Teaching by telling; teachers can tell students the important basic ideas of mathematics such as facts, concepts and procedures

Level 2: Teaching by explaining; teachers can explain the meanings and reasons of the important basic ideas of mathematics in order for students to understand them

Level 3: Teaching by guided ‘rediscovery’; teachers can provide students opportunities to understand these basic ideas, and support their leaning.

Ellenberg (2015, p.56) describes the ‘war of teaching’ styles that continues to rage amongst mathematics teachers in the USA: “On one side, you have teachers who favor an emphasis on memorisation, fluency, traditional algorithms, and exact answers; on the other, teachers who think maths teaching should be about learning meaning, developing ways of thinking, guided discovery, and approximation.”

Ellenberg does not align himself with either ‘side’ and believes the best mathematics teachers are drawing on the best bits from both camps: “we have to teach a mathematics that values precise answers but also intelligent approximations, that demands the ability to deploy existing algorithms fluently but also the horse sense to work things out on the fly, that mixes rigidity with a sense of play.”

From the Preparing Teachers and Developing School leaders for the 21st Century, Lessons from Around the World report (ed. Schleicher, 2012, p.38) “there seems considerable agreement across countries regarding important attributes that 21st century learning environments should provide.” These include:

- encouraging engagement
- ensuring learning is social and collaborative
- acknowledging students’ motivations and the significance of emotions
- be demanding of every student without overloading
- promoting connections across activities and subjects
- using assessments that emphasise formative feedback.

From the above, it could be argued that great teaching requires great empathy and that great learning takes place in a social, collaborative, emotionally aware environment; an empathetic environment.

It may be interesting to note at this point, that the emphasis on the delivery style of Core Maths would link with many of the above: encouraging engagement; learning as a social and collaborative activity; promoting connections across activities and subjects; and so forth.

Ultimately effective teaching and learning is about human connections and relationships, and it appears that the behaviour of effective teachers and less effective teachers are not easily characterised; much depends on the particular way that teachers and students relate together (Coe et al, 2014, p12).

Could this perhaps be summed up by Rita Pierson in her TED talk: “kids don’t learn from people they don’t like”?

3. Why is there a shortage of effective mathematics teaching?

There are particular characteristics of why mathematics suffers more from teacher shortages than many other educational disciplines, and why it is a particularly stubborn problem. Here are some of the reasons:

1. *Maths graduates simply have more options*

> Schools, in looking for physicists and mathematicians, are competing not just against other schools, but major financial institutions and blue-chip companies (Smithers and Robinson, 2013, p.53); in trying to recruit qualified mathematicians into teaching, we are competing with other employment opportunities for mathematicians … perceived as considerably more attractive than teaching… (Smith, 2004, p.5)

2. *There are simply not enough graduates of maths and science*

> One of the reasons for the shortage of science and mathematics teachers in the UK, particularly in England, is that graduate output in those subjects is too low. (Smithers and Robinson, 2013, p.50)

3. *As a direct result from the above two points, maths and science graduates entering the teaching profession are less well qualified than their counterparts in other subjects*

> … in those subjects where there is more competition for places three-quarters or more of the trainees have at least an upper-second: history (83.3 per cent); drama/dance (78.5 per cent; English (76.9 per cent); and classics (75.0 per cent). But trainees in the sciences and mathematics were much less well qualified. The lowest percentages of good degrees were in ICT (49.5 per cent), mathematics (51.5%) and science (54.0%). (Smithers and Robinson, 2013, p.38)

4. *A potential dichotomy in the personality-type most attracted to teaching and the personality-type most attracted to shortage subject areas; the theory being those interested in mathematics are less likely to be interested in spending time with people*

> Teaching is a people-oriented profession par excellence. It is essentially about being with people and helping them. If they are key values for you then there is ample opportunity in teaching to express them, but if you are happier with things than with people, teaching may not be for you. Subjects differ considerably in the personality-type they attract (Smithers, 1969; Ormerod and Duckworth, 1975) and in the appeal of teaching (Rosenberg, 1957; Smithers and Hill, 1989). Physics and drama are at the opposite ends of the spectrum (Smithers and Robinson, 2013, p.22)

5. *Lack of subject specialists in formative (primary) years, creates the conditions for future shortfall of graduates*

> Finland and South Korea, where graduate output is sufficient, build from the bottom having subject specialisms in the training qualification for primary school teachers…there is a strong case for training more teachers with science and mathematics specialisms for primary schools in the UK. (Smithers and Robinson, 2013, p.50)

4. What other countries are doing?

Finland, Japan, Singapore and South Korea are notable amongst countries with strong mathematics teacher workforces. As reported by Smithers and Robinson (2013, p.53) these countries share similar characteristics:

- teaching is a high status profession
- there are sufficient mathematics graduates
- they have good planning and monitoring models
- they are able to carefully select trainees
- they have effective teacher preparation programmes
- the qualifications are respected
- there is systematic professional development throughout their career
- the working conditions are good

Ideally countries, struggling to recruit and retain mathematics teachers, would be able to emulate these countries and adopt similar strategies such as promoting attractive pay, good working conditions, recruiting high calibre trainees, proper professional development and the pursuit of high status for the profession. Indeed England has tinkered and trialled many approaches to achieve exactly this aim. The recent Government has made some attempts to make the profession more difficult to enter, has offered generous bursaries to those with the highest qualifications and is expanding the Teach First initiative (which recruits highly qualified graduates from prestigious universities). Although raising the bar to enter the profession may make sense in the long run we already have a shortage of maths teachers and we need more trainees now. Offering attractive cash handouts to impoverished graduates may 'bump' recruitment figures but is unlikely to wed them to the profession. And retention is a huge issue in its own right.

Attracting 'bright things' into the profession is in the spotlight, and rightly so, but keeping them there should command equal focus. It could be reasonable to suggest that it takes somewhere between 5 and 7 years for a teacher to acquire high skill levels (Berliner, p14). In the UK we lose around 50% of our mathematics teachers within 5 years of being trained; Before time and experience can mould them into really effective practitioners, they are gone.

Good working conditions and the profession being held in high regard are likely to be key factors for retention. But the issue of status is a tricky one. Status can not be simply bought or willed into existence; status evolves. Nevertheless the ingredients to engineer this process can be willed into existence: a professional body for teachers, enviable working conditions, professional development as a requirement, political will.

Undoubtedly cultures and history play a significant part in the success or otherwise of recruiting maths teachers and it may not be as simple as emulating others' ideas. Nevertheless both Finland and South Korea have shown that sea change is possible (in a relatively short period of time, about

30 years) and so we are not necessarily chasing an impossible goal. Chung (2010) cited in (Smithers and Robinson, 2013, p.14) cautions against transposing policy directly from Finland but suggests at least two pointers worth pursuing:

- find ways to make teaching maths sufficiently attractive so that recruitment can be highly selective

- ensure that there are maths specialist teachers in primary schools

Creative and imaginative solutions are being sought in various countries such as Australia and the Netherlands with as yet limited effect. Could this tie in with the idea that no matter what you do, mathematicians and physicists are always going to be less attracted to teaching (see the dichotomy of different personality types discussed earlier)? Countries in East Asia are far more successful with their recruitment of mathematics teachers; their 15 year olds are then unsurprisingly far more successful in international comparative mathematics tests such as PISA.

Many reasons for the success of East Asia have been suggested, amongst them that the culture of obedience means that teaching is far more about delivering the subject material and far less about interacting and managing children. Thereby the ‘personality dichotomy’ becomes less significant. In addition cultural emphasis and pressure to succeed academically, is clearly much greater in East Asia; this inevitably leads to a greater pool of mathematics and science graduates.

5. What is the impact of mathematics teacher shortages?

As a result of teacher shortages in mathematics, many teachers are required to teach outside their subject domain with little or no further training. In addition, the criteria for new recruits are lowered and the problem of poorly qualified practitioners becomes self-perpetuating.

In the UK we have no requirement for subject specialists in primary and many non-specialists teach maths in lower secondary (and beyond). As Howson (2002, p.81) says: “the majority of teaching in KS3 (11 - 14 age range) appears to be given by teachers whose degrees were not in mathematics but, at best, in a mathematically-related subject.”

Marshall (2013, p15) notes that teacher effectiveness may be “the single most important lever for governments and schools to pull” in raising student attainment and that “replacing a poorly performing teacher with a very effective teacher had a dramatic impact, especially on the attainment of disadvantaged pupils”. It was found that a difference of a year’s worth of learning could be gained, with very effective teachers compared with that achieved with poorly performing teachers.” This was an echo of Smith’s (2004) findings: “we have a serious shortage of specialist mathematics teachers in schools and colleges and this is having an adverse effect on pupils' learning experiences." All of this is backed up by the findings from Ofsted (2012, pp. 4-10):

- too many pupils who have a poor start or fall behind early in their mathematics education never catch up. The 10% that do not reach the expected standards at age 7 doubles to 20% by age 11 and nearly doubles again by 16.
- improving the consistency and quality of teaching within a school is crucial if all pupils, rather than some, are to make sustained good progress.
- less experienced, temporary and non-specialist teachers were more likely to teach lower sets or younger pupils.
- Schools should: develop the expertise of staff

6. What can be done? How do we get more effective teachers?

Recruiting teachers from overseas could help, and many countries including the UK are actively doing so. But this simply shifts the problem from one part of the globe to another, and does not really address or solve the shortage.

Increasing the use and effectiveness of technology could help relieve the shortage of maths teachers. Computers are used to set and answer questions, with more and more sophisticated software becoming interactive to enhance the experience. Undoubtedly there is an exciting future with technology and it may not be that unrealistic to imagine holograms for teachers in the not so distant future. But technology - although very useful - is only a tool. Face-to-face interactions cannot be totally replaced. As reported by Smithers and Robinson (2013, p.iii):

> *in essence, [schools] have not changed that much since Roman times, because at heart it is the personal contact that really matters. Whatever the technological advances, there will still be a substantial requirement for science and mathematics teachers.*

Reorganising schools with super-sized maths classes maybe an option. As too, schools in the cloud using Self Organised Learning Environments (SOLE) as made popular by Sugata Mitra (TED 2013), a professor of educational technology at Newcastle University, UK. This powerful idea of students being responsible and instrumental in their own learning using today's technology, clearly captured the imagination of one teacher in Mexico, Sergio Juarez Correa. And yet it was not the technology (old, broken and often without internet connection) that sparked the children and transformed their lives - but this teacher's passion, his belief in what could be achieved, his human connection with the children.

Sir John Jones was once asked: Why do we need teachers when we have Google? He waited awhile before being gifted the answer by another student: Teachers don't teach you the subject, they teach you the love for that subject.

Sir John Jones concurred: good teachers demonstrate passion for their subject and for their teaching of that subject.

So - another piece of the puzzle to solve the shortage problem could be to 'retrain' good teachers from other disciplines to become effective mathematics teachers. This is something that is now being trialled and tested in England and is now called Teacher Subject Specialism Training (TSST). Can this work? And will this help address the 'personality dichotomy' problem? Could teachers from other disciplines, for example, be attracted to the new Core Maths course and 'simply' need to be 'up-skilled' to teach this qualification? Or could it just make the situation worse: certifying participants who are in fact not well qualified at all?

Currently retraining is offered (although not necessarily well known about) to all teachers in England with QTS.

7. Teacher Subject Specialism Training (TSST)

Over the past 3 years in the UK, Post-ITT Subject Knowledge Enhancement courses (recently renamed as Teacher Subject Specialism Training (TSST)) have helped increase the number of teachers of mathematics. The Centre for Innovation in Mathematics Teaching (CIMT) at Plymouth University has been teaching these one-year courses in a variety of locations, based on e-learning for subject knowledge and face-to-face meetings for reinforcement and enhancing pedagogy with the aims:

- enhance participants' mathematical knowledge to give confidence to teach up to and including Higher Level GCSE Mathematics;
- inspire and enthuse teachers;
- provide motivating introductory activities, tasks and presentations for teaching mathematics

Now TSST is set to be a major strand in the government's overall strategy to build a long term model to tackle the enduring problem of teacher shortages. No longer can we solely rely on 'flow' into the profession to fulfil quotas; utilising current 'stock' by retraining and up-skilling current teachers is seen as a possible long term sustainable solution (Watterson, T., 2015). Similar courses are now being set up for teachers of Core Maths, with an emphasis on attracting 'returners' to the profession.

As a course tutor for TSST, I have recently been following Case Studies from the 2014 cohort of participants. The participants were 'retrained' over a period of one year, participating in teaching and learning opportunities involving: active participation; group work; collaborative lesson planning; problem solving activities; interactive sessions; reflective journals; research input; and resources evaluation. The interweaving of pedagogy and mathematical content was integral to this course.

The ethos of the TSST courses has been to develop this pedagogical understanding of teaching mathematics. Conceptual understanding, active participation and the building of connections have been major constituents of this course. And this is exactly the same ethos being promoted for the delivery of Core Maths. Employing this model of training for teachers of the new Core Maths qualification is eminently sensible.

One of the early themes emerging from this research includes the value of lesson observations, mentoring and feedback.

8. Lesson observations, mentoring and feedback:

Lesson observations and mentoring were not part of the programme being delivered to the 2014 cohort. However lesson observations play a central role in my research and data gathering, and so all my case study participants are regularly observed teaching, receive feedback and a mode of mentoring and coaching. Alongside these observations, questionnaires and interviews are conducted to incorporate various viewpoints of the same subject matter (triangulation). Further interviews with senior teachers, field notes and conversational dialogue are adding to the perspectives.

Emerging from the study is the value the participants put upon the feedback and support emulating from these developmental lesson observations. The lesson observations are 'developmental' in the sense that the teachers are given individual themes to focus on from one observation to the next.

Having now observed many lessons and conducted numerous interviews, it is beginning to emerge that ongoing lesson observations and the associated mentoring should be integral to any TSST programmes. Ongoing and sustained support will be the only way to capitalise and consolidate the gains made during training. Just as NQTs have support and a reduced teaching load in their initial year, we should look to emulate this model for newly 're-trained' teachers. One headteacher interviewed recently, said that although in an ideal world this would be pragmatic, fully experienced members of staff are unlikely to be granted such lee-way in terms of time. However he did strongly concur we should be committed to ongoing mentoring and support for these newly 'up-skilled' teachers.

Linking with the above, are two other early emerging themes from my research: Lesson Study as a model for collaborative and sustainable professional development; and the value of senior management support. These will be discussed in future papers.

One other strand has emerged from the theme of lesson observations: participants of a TSST course should be observed teaching mathematics before being awarded certification of any kind. This has emerged from teacher evaluations where some people believe the certification would be of greater value and guarantee more quality assurance, if participants were assessed practically. This view is supported by some senior teachers who have identified this as an issue.

It is clear (from the teachers) that if such an observation assessment should take place, the evaluator cannot be the course tutor/mentor but should be an external evaluator. The role of the course tutor/mentor is to encourage and support participants and foster a collaborative and safe environment in which participants can learn and develop and this would be compromised if participants knew they were also to be judged by said person.

9. Potential limitations of TSST

Is TSST part of the solution - or just creating an even bigger problem: semi-skilled mathematics teachers filling the void of teachers in classrooms but not filling the ‘expertise’ gap? Will we be kidding ourselves that we have cracked it - when all we have done is satisfied a head count? In fact will we be certifying weak practitioners, fooling potential employers and unleashing poorly trained teachers onto unsuspecting students? As Howson points out there is a difference between qualified mathematics teachers and teachers who teach mathematics, “– and here we must firmly distinguish between the shortage of *qualified* teachers and the now growing and more readily apparent shortage of teachers who may be required to take mathematics classes”(2002, p.80). In general Howson argues for teachers of mathematics to have degrees in mathematics or a least a mathematically related subject. He does acknowledge that teachers without the best qualifications can be outstanding and likewise that teachers with the highest qualifications may be poor practitioners but nevertheless he uses the words of a 1912 Staff Inspector for Mathematics to succinctly stress the point: “The efficiency of teachers [cannot]… be measured by… academic qualifications. None the less when the question is not of an individual or of a small group, but of a large number, it remains true that the lack of good qualifications must seriously limit the efficiency of teaching.”

Perhaps we should we be thinking far more radically? Do we actually need more mathematics teachers? We could instead focus on having fewer mathematics teachers, and work hard to retain the best ones we have: raise the cachet and simultaneously raise the bar for recruitment; select only the very best candidates; remunerate handsomely. Advancing the status this way could drive a demand for this career choice. Fewer specialists, with higher salaries and attractive terms and conditions, could be the basis for a long term sustainable plan.

10. Conclusion

We have a shortage of mathematics teachers in the UK. We now have the chance to see if TSST, one of the UK Government’s major planks in its plan to improve mathematics instruction, can deliver a sustainable way of helping the nation to improve its mathematical provision. This, at a time when the new post-16 Core Maths qualification will place greater demands on an already overstretched supply of mathematics teachers.

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