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TOWARDS AN EFFECTIVE NATIONAL STRUCTURE FOR TEACHER PREPARATION AND SUPPORT IN MATHEMATICS

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I recently spent three weeks at a university, where the Head of the Mathematics Education Department had a joint appointment in Shanghai, and had been closely involved in the England-Shanghai teacher exchange. In the office next door to mine was a young researcher from Shanghai, who had served as lead chaperone for the first group of Chinese teachers visiting England. I explained what I saw as the response at the England end of the exchange, and tried to get them to reveal how their colleagues at the Shanghai end viewed things. After two weeks of diplomatic pussy-footing, the barriers came down, and I was told quite forthrightly:

> "If England wants to learn anything at all from this exchange, they will have to come to terms with the whole preparation-plus-support cycle for Shanghai teachers – starting with the way they are trained, how they learn to view mathematics teaching, how lessons and textbooks are developed and refined, and how they see gradual improvement as a communal activity."

The perennial shortage of competent mathematics teachers causes difficulties for many end-users – including those in Higher Education. University mathematics departments depend on school and college teachers to prepare undergraduate students; yet these mathematics departments have mostly hesitated to ask whether some supplement to, or adjustment of, existing undergraduate programmes might help to address recurrent maths teacher shortages.

There are nevertheless signs that many university mathematics departments would (in principle) be willing to work with government, and with colleagues in Faculties of Education, to ensure a more reliable flow of suitable, and suitably trained, students into mathematics teaching. However, given the current state of teacher preparation and support in England (supplemented by an ever-more-desperate array of emergency measures), **an honest, open debate concerning the requisite national institutions and structures** would seem to be a prerequisite for concerted action on this front.

We hope this discussion paper might help to stimulate such a debate – and that this debate might ultimately lead to an improved, and sustainable *national framework of teacher preparation and development*, to which university mathematics departments might feel able to contribute more actively than in the past.

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Ten points

1. Everyday life in a modern society is increasingly dependent on mathematics. Hence every country needs to achieve more effective mathematics teaching for many more students than in the past.

2. This will require much work – not least because a consensus about ITE and CPD presupposes a shared view of the kind of teaching that is needed in schools, and how in-service teachers come to understand – over many years – the disciplines they profess to teach (e.g. through the use of carefully developed textbooks), and hence how one must prepare and support teachers to facilitate school students' long-term mathematical progression. In the absence of such a consensus, there is an obvious danger that we will simply repeat the errors of recent initiatives (from efforts following the Cockcroft Report, the introduction of GCSE, the National Curriculum, the Numeracy Strategy, and more recent reforms), which have repeatedly been implemented

- without first clarifying, and working to achieve agreement concerning, the problems to be addressed, and
- without then taking time to design, to test, and to refine each proposed solution before roll-out (and later to engage in an honest review of its impact).

To give just one example: enormous efforts have been made over the last 20 years to improve the teaching of mathematics at *primary* level. And there have been impressive rises in *average* performance (e.g. in Year 5 – as measured by TIMSS 2003, 2007, 2011, 2015). Yet the efforts that led to this "improvement" were focused on **short-term goals** (e.g. raising scores on Key Stage 2 SATs). And there was then no consequent debate when this "improvement" had **no evident impact on students' preparedness for mathematics at Key Stage 3** (for example, as measured over the same period 2000-2015 by TIMSS and PISA in Years 9 and 10, or by the ICCAMS project). Hence the considerable efforts invested at Key Stage 1 and Key Stage 2 would seem to have been misdirected.

3. Despite much political rhetoric concerning "evidence", there appears in some quarters to be a lack of interest in gathering the most obvious evidence, or in learning from it when it becomes available.

The poor quality of secondary school mathematics teaching in England owes much to the shortage of specialist teachers: see, for example, the tables and text on pages 125-129 in the TIMSS 2015 national report for England[†]

The evidence from TIMSS and PISA (and from the ICCAMS project, which used secondary test items originally from the late 1970s CSMS project on a matched national sample 30 years later) shows clearly that the substantial, and sustained rise in TIMSS average scores in Year 5 *has been accompanied by few signs of improvement*

[†]`https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/572850/TIMSS_2015_England_Report_FINAL_for_govuk_-_reformatted.pdf`.

(and, in important areas, a significant decline) in performance in Year 9 and Year 10. It is hard to resist the conclusion that focus on short-term test preparation at Key Stages 2-4 has diverted attention away from laying **forward-looking** mathematical foundations for all students. The same inference would appear to explain some of the recent difficulties experienced by visiting Shanghai mathematics teachers when trying to teach English Key Stage 3 classes.

These studies reveal that we devote **less than the international average amount of time** to mathematics teaching in secondary schools. Yet Ministers hesitate to insist that more time be spent (even as an aspiration) – perhaps because to do so would open up to public discussion our persistent failure to ensure *a sufficient supply of qualified mathematics teachers.*

TIMSS and PISA also show that, despite explicit attempts to "differentiate" at both ends of the attainment spectrum, England somehow manages to produce around half the international average number of students in Years 9 and 10 who can handle harder problems (TIMSS "Advanced" level, or PISA "level 6"), and produces a longer tail of poorly performing students than many other countries.

4. Mathematics **can** be effectively taught. But there is no magic bullet. Improving the teaching and learning of mathematics has to be a **long-term** project.

Though there may be no simple solution, yet there are some acknowledged *necessary* ingredients. For example, trainee teachers need an initial understanding of the structure of elementary mathematics, of its central ideas and methods, of the didactical analyses which suggest how these ideas and methods can be most effectively taught (e.g. in order to avoid – or to confront and correct – common misunderstandings), together with some awareness of the resources which are available to support this process. In particular:

- ITE is a highly specialised craft, which needs specialised practitioners in dedicated institutions (like East China Normal University in Shanghai, or NIE in Singapore, or ...); and
- high quality mathematics textbooks are needed to provide newly qualified teachers with a map allowing them to explore, and to get to know, terrain that they will have only partly grasped up to that point.

Establishing the necessary background takes time – and the opportunity to make mistakes – under the guidance of those with appropriate cumulative experience. Some of the relevant experience is certainly to be found in schools; but the experience of any particular school is inevitably idiosyncratic, and so lacks the wider perspective which is needed when preparing trainee teachers for their future profession.

This need for expertise in teacher preparation, focused in a relatively small number of specialist institutions, is clearly understood in other countries – including those which are regularly held up as examples from which we should learn. However, instead of challenging and improving the traditional HEI-based approach to teacher preparation and support in England, successive administrations since 1997 have sought to **replace** this traditional structure by a decentralised school-based "system", where trainees learn "on the job", from practising

teachers. The approach may appeal to those who assume mathematics teaching is a simple process; but it deprives trainees of the necessary broader perspective, has tended to eliminate the basis for informed professional reflection, and would appear to have **reduced** the extent of good mathematics teaching in England. Recent emergency programmes (such as TSSTs) tend to further obscure what is needed if mathematics teaching in the UK is to become more effective in the longer term.

5. In effective systems of teacher preparation and development, the necessary specialist ITE experience (combining mathematical competence, teaching experience, and years spent working with trainee teachers) is nurtured by **focusing training centres in selected HEIs**, or in teachers' colleges. These centres of expertise then work closely with teachers-in-post throughout their professional lives.

6. Twenty or so years ago, the system of *teacher preparation and development* in England was shared between HEIs, teachers' colleges, and Local Authorities. This system has since been actively changed by successive administrations in favour of a more pliable, decentralised (also more expensive and wasteful) "school-based" approach, linked to Teaching Schools, SCITTS, School Direct, Teach First, etc..

At the same time all manner of bursary schemes have been tried – with no attempt to assess whether they have been effective in attracting new applicants, or whether they have delivered any kind of "value for money".

These points are made repeatedly – and rather bluntly – in the February 2016 report *Training new teachers* from the National Audit Office [NAO]. The report recognises the central role of teacher training, while spelling out the weakness of the DfE's current approach. We include a few sample quotes (not specific to mathematics) from the opening pages of the report.

- "Teachers are critical to the success of all money spent in England's schools." (page 5)
- "28% [of all newly qualified teachers across all subjects] had left [state schools] within 5 years" (page 8)
- "The Department does not have data that allows it to quantify teacher shortages reliably." (page 9)
- **"The Department is yet to demonstrate how accurate [its] model and its own judgements are"** (page 9)
- "The Department has not assessed the impact of bursaries on applicants' success or the number who go on to qualify and teach." (page 11)
- **"The Department has insufficient information to ensure the cost-effectiveness of its approach"** (page 11)
- "The Department has information about the short-term cost of training routes but does not yet have sufficient information about long-term costs and the extent to which each route, and increasing schools' role in the process, has improved teaching standards" (page 11)
- **"The Department's short-term approach means providers do not have a clear, stable basis on which to plan for the long term**. (page 11) "
- "The Department does not yet have the information it needs to understand how

> different routes into teaching impact on schools' ability to recruit and retain newly qualified teachers, and cannot yet demonstrate how new arrangements are improving the quality of teaching in classrooms [...] until the Department meets its targets and addresses the remaining information gaps, we cannot conclude that the arrangements for training new teachers are value for money." (page 13)

Given its remit, the NAO report focuses on *financial* matters, and does not address the efficacy (or otherwise) of the underlying national approach to teacher preparation and support, or of its impact on mathematics teachers. The subsequent NAO report *Retaining and developing the teaching workforce*, September 2017[†] and the Public Accounts Select Committee report with the same title, January 2018[‡] provide additional details, without asking whether there is any evidence that the current fragmented system could ever work. Recent trends data presented by Professor John Howson at the All Party Parliamentary Group on *The Teaching Profession* (22.5.18) suggests clearly that tinkering is no longer a defensible option. (I could not find an e-version of these statistics – taken from UCAS; but John Howson's blog is at ([§]))

7. In short, England has engaged in a massive experiment in teacher preparation and support, without any effective piloting, and no evident attempt to collect the evidence that might make it possible to assess the approach currently adopted.

The International Commission on Mathematical Instruction (ICMI) sponsors a series of "studies" on important themes. Their 15th Study T*he organization of the mathematics preparation and development of teachers* (2009) made it clear (Chapter 1.1.1, M.T. Tatto *et al*) that England's current "school-based" approach is out of line with the systems adopted in other developed countries.

Most systems prefer an initial period of training (in an HEI, Teachers' College, or Institute of Education), *followed by* a period which addresses some of the practical aspects of *teaching in school*. Other systems blend these two aspects of teacher preparation slightly differently – **but with overall responsibility being routinely vested firmly in the HEI**, or equivalent institution. In particular, each provider recruits, and uses their accumulated expertise to guide the progress of, **a significant number** of *potential teachers in their area of specialism*.

We know of no other system that pretends to train mathematics teachers by placing small groups of trainees at the mercy of teachers with no relevant ITE experience beyond being themselves teachers, with much of the input being "generic" rather than subject-specific. England appears to be alone among developed nations in embracing such an approach.

[†]https://www.nao.org.uk/press-release/retaining-and-developing-the-teaching-workforce/.

[‡]https://publications.parliament.uk/pa/cm201719/cmselect/cmpubacc/460/46002.htm

[§]https://johnohowson.wordpress.com/.

One result of this flight from "expertise" is that no-one (not even the Department for Education) takes national responsibility for oversight of the programme, or for analysing what is needed to train and to support specialist teachers, or for assessing the efficacy of the current system. Instead funding levers are used to *play providers off against each other*. Moreover, the resulting shortage (for which the Department is responsible) then exerts pressure on schools to volunteer as, or to join consortia with, "Teaching Schools" **so that they gain direct access to those recruits that are available**.

8. Recent curriculum reforms in England (since 1997 say) have misconstrued teaching as a largely bureaucratic enterprise, which can be centrally controlled by largely bureaucratic means (inspections, testing, performance indicators, league tables, targets, etc.), and by exerting bureaucratic financial controls. This has succeeded in keeping everyone on their toes, but at the cost of undermining good teaching and creating a certain kind of uniformity *that misses the point*. **Similar mistakes have been made in recent "reforms" affecting teacher preparation and support.**

These changes have failed to address the nature, and the key importance of, good mathematics teaching. We repeat the comments from key observers at the Shanghai end of the recent England-Shanghai teacher exchange – to the effect that

> **little more can be learned "unless you in England are willing to reconsider your approach to initial teacher preparation and development".**

We do not recommend that we should "copy" this or that country. But it is worth trying to learn from systems – such as Finland, or Singapore – which have clearly "improved" their preparation and support for mathematics teaching over the last 30 years or so.

Both Finland and Singapore found themselves in some difficulty in the late 1970s and early 1980s; and as part of their response, both countries adjusted not only their curriculum, but also their teacher preparation, and their support for serving teachers (textbooks, CPD, etc).

Good mathematics teaching is a profound "craft" (combining deep subject knowledge, a sensitivity to the dynamics of learning, and key supporting structures). Yet even countries which have a plentiful supply of excellent teachers **do not conclude** that teacher preparation can be largely reduced to "learning on the job": rather they establish **national institutions** that cultivate the necessary professional expertise.

In effective systems, there is also a contribution from "science" (educational research) – though this seems to be relatively modest.

We, in contrast, have tended to overvalue the "science" (which rarely translates into something useable at scale).

We have also failed
(a) to respect and to cultivate the basic "craft" of mathematics teaching,
(b) to establish the requisite institutional ITE/CPD structures to prepare and develop mathematics teachers, and
(c) to identify and develop the essential ingredients (timetables, textbooks, whole class teaching, classroom/work habits, ...) that facilitate the basic craft.

Moreover, even where we have begun to engage with matters directly relevant to mathematics teaching (as with textbooks, whole class teaching, mastery, etc.), we have still tended to "dabble" – training *small numbers* of teachers in *"generic"* aspects, rather than focusing on achieving

a profound understanding by all teachers of the structure
(i) of the underlying *principles*;
(ii) of *specific programmes*, and
(iii) of the details of their effective implementation.

For example:

- NCETM and the Maths Hubs actively prevent discussion of specific programmes;
- financial support is only available for textbooks, rather than for the more important training;
- the primary textbook projects have been left to devise and implement their own training – with very variable results, and no open assessment or guidance; and
- we have so far found no way to support the development of appropriate textbook schemes at Key Stage 3.

In other words, **we have so far failed to establish institutional structures which could guarantee a regular flow of trainees, which supports those trainees once they are in post, and which might mediate important ideas on a national scale.**

9. Like Mathematics itself, mathematics teaching is an elusive art. One cannot simply place (even impressive) individuals in the classroom, impose an array of rewards and penalties, and expect this to result in widespread effective mathematics teaching.

Mathematics is in some ways "personal"; but it is also *universal*. We need teachers who understand this through their own engagement with the discipline. And we need ***specialist*** *teacher trainers* who understand how to open up this fascinating universe to those who wish to become mathematics teachers.

For the adult, Mathematics is a *mental universe* – a universal abstract world *inside our heads*. Each learner must somehow internalise the main ideas and methods of Mathematics to make them his/her own.

Some of these ideas and methods are "refined common sense", and should ultimately be seen to be "natural" by most students.

But grasping other ideas and methods can prove seriously challenging – especially where these methods were hard-won by great minds, over many centuries. One would like many students to appreciate their naturalness *retrospectively* – but they may not find this easy at first.

These observations underline key tensions which mathematics teaching has to confront. We all try to understand new ideas and methods in terms of what we already know. This kind of adjustment is what Piaget called *assimilation*, and arises whenever a learner is confronted with a task in what Vygotsky called their "zone of proximal development". Such adjustment is entirely natural – though the challenge to "succeed" can incline the learner to continue using "backward-looking" methods, which still deliver acceptable "answers".

However, the most important transitions in learning mathematics occur when *assimilation* proves insufficient, and the learner is obliged to *change focus* (as happens when one moves from finger counting to place value, from simple addition to subtraction, from additive to multiplicative thinking, from positive whole numbers to the arithmetic of negative numbers, or from calculating with numbers to working with symbols). The kind of adjustment that is then needed is what Piaget called *accommodation*. It requires a shift from what is familiar to something new. At such a stage each learner has to reinterpret what they thought they knew in fresh terms, and must learn to use "forward-looking" methods even for those operations where s/he already has apparently effective ("backward-looking") tools.

We need teacher educators who understand such details, and who ensure that intending teachers are sensitive to them, and their implications for the classroom. **This is impossible to achieve within a fragmented, strongly school-based approach to ITE.**

10. Teachers and schools in England may now work harder than ever, and in a more focused way. Schools have learned how to improve short-term measured performance of the simplest kind. **But long-term progress (e.g. achievement at age 16 or 18, or beyond) has, if anything, worsened, and fewer teachers now have the perspective, or the confidence required to take the kind of long-term view that is needed to understand why**.

The evidence for this claim is manifold, and entirely consistent:

- from the 1995 LMS report *Tackling the mathematics problem*[†],
- from TIMSS,
- from ICCAMS,
- from the Ofsted triennial reports 2008 *Mathematics: Understanding the score*[‡] and 2012 *Mathematics: Made to measure*[§], etc

[†] http://mei.org.uk/files/pdf/Tackling_the_Mathematics_Problem.pdf.

[‡] http://dera.ioe.ac.uk/9459/2/A9RAB12_Redacted.pdf.

[§] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/417446/Mathematics_made_to_measure.pdf.

The fact that the overall performance of the system is not as healthy as is often claimed **needs to be understood before attempting any diagnosis of the efficacy of teacher preparation and support in England, and before proposing any cure.**

We offer the following very brief summary – at primary, secondary and tertiary levels:

- TIMSS Year 5 average scores have continued to improve since 1999; but this may well reflect a dependence on *primitive* methods, which effectively *obstructs* subsequent progress – for the "improvement" has had very little impact on performance at Year 9 and above.
- A level Mathematics entries have risen steadily since the debacle of 2002 – thanks to the efforts of many sections of the profession. But it is well-documented that the level of understanding reached, and the meaning of the grades awarded has suffered.
- UK university mathematics departments vary enormously. Many appear to be in rude health. But all have achieved this by recruiting extensively from other countries. In a number of cases, *home-grown undergraduates are now in a minority* – a trend which is more acute at postgraduate level, and which is *even more marked for staff appointments*.

Conclusions

A: Every effective system we know recognises that teacher preparation and development is a *specialist enterprise* – requiring suitable specialists with many years of experience, interaction, experiment, and reflection.

As befits such a "specialist enterprise", effective systems recognise that teacher preparation needs to be sufficiently "concentrated" to ensure

- that the applications process is handled efficiently
- that the resulting cohorts are of a predictable size and quality
- that every trainee is guided by suitably experienced specialists, who are aware of, and who are accountable for, mediating current policy in a consistent way.

In contrast, England has adopted a system in which the need for expertise has been largely replaced by self-serving competitive bidding from inexperienced, small providers, combined with a touching faith in the virtues of learning "by sitting at Auntie's knee".

B: Effective preparation and training requires a limited number of **national** institutional units, linked as part of a national effort, and subject to central guidance.

For recruitment and provision to be efficient and effective, each unit should deal with a significant number of students in each area of specialism (say 20–100). In most systems the initial period of preparation tends to be either

- a "degree programme" of 4-5 years (e.g. for primary teachers), with substantial subject-specific elements, or
- an initial specialist, subject-based degree (of 3+ years), followed by (usually 2 years) of pedagogical and didactical training, with some school experience.

In most systems, this initial teacher preparation continues into the first years of teaching (as was originally proposed in the mathematics strand of the 1998–99 *Initial Teacher Training National Curriculum*, and as is partly recognised by the recent proposal to extend QTS to 2 years). This initial preparation is then supplemented by systematic lifelong (largely subject-specific) professional development.

C: In place of such a proven structure, England has adopted a succession of ad hoc schemes (for school-based programmes; wasteful bursaries; TSSTs; etc.) – none of which appears to have been suitably piloted or monitored.

> We do not underestimate the courage that will be needed to reverse recent changes. But the ever-increasing pressures (e.g. in response to the NAO report, the increased demand in schools, the development of mathematics beyond age 16, and the failure of the current approach) leave us little choice.

University mathematics departments could contribute significantly to a fresh approach. But it is hard to imagine a rational framework within which they might make such a contribution that does not first develop a modern institutional, HEI-based structure to replace the current experiment of school-based ITE.

About the author

Tony Gardiner (born 1947) is a British mathematician. He was responsible for the foundation of the *United Kingdom Mathematics Trust* in 1996, one of the UK's largest mathematics enrichment programs, initiating the Intermediate and Junior Mathematical Challenges, creating the *Problem Solving Journal* for secondary school students and organising numerous masterclasses, summer schools and educational conferences. Gardiner has contributed to many educational articles and internationally circulated educational pamphlets. His most recent publications include three books of extension materials ("Mathsteasers") for ages 8-13. As well as his involvement with mathematics education, Gardiner has also made contributions to the areas of infinite groups, finite groups, graph theory, and algebraic combinatorics.

In the year 1994–95, he received the Paul Erdös Award for his contributions to UK and international mathematical challenges and olympiads.

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