MIND THE 'GAPS': PRIMARY TEACHER TRAINEES' MATHEMATICS SUBJECT KNOWLEDGE

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Recent changes in the curriculum for Initial Teacher Training incorporate a stronger focus on trainees' subject knowledge. (DtEE, 1997) Some evidence would seem to support this shift of emphasis. In the US, Kennedy's research (1991) suggested that teachers' mathematical understanding is frequently limited, whilst in the UK Alexander *et al* (1992) called for improvement of the knowledge base of teachers in order to improve the teaching of mathematics. Inspection evidence identifies teachers' lack of subject knowledge and confidence in mathematics as being a contributory factor in low standards of mathematics attainment of pupils (Ofsted, 1994).

Circular 10/97 (DtEE, 1997) sets out what is considered to be the "knowledge and understanding of mathematics that trainees need in order to underpin effective teaching of mathematics at primary level". From September 1998, audit and remediation of students' subject knowledge is statutory.

> All providers of ITT must audit trainees' knowledge and understanding of the mathematics contained in the National Curriculum programmes of study for mathematics at KS 1 and KS2, and that specified in paragraph 13 of this document. Where gaps in trainees' subject knowledge are identified, providers of ITT must make arrangements to ensure that trainees gain that knowledge during the course ... (DtEE, 1997, p. 27)

In this paper, we describe our approach to the audit of the mathematics subject knowledge of a cohort of 154 trainees following a one-year primary PGCE course, and we offer some preliminary findings. Our research follows a number of different directions; here, we offer a (fore)taste of each of them.

APPROACH AND TIMING

The structure of the primary PGCE at the Institute is perhaps unusual, in that the methods course for each core curriculum subject is taught in three intensive 5- or 6-day blocks, one in each term. The blocks for mathematics are timetabled first in each term, so that by the middle of January, with fully six months of the course remaining, the main content areas - number concepts and operations, data handling, mathematical processes, shape and space, measures, algebra, probability - have been 'covered' in lectures and workshops. This therefore seemed to us to be the optimum moment for an audit of subject knowledge, giving the trainees maximum opportunity and professional motivation to recall topics they had forgotten (for lack of use) since they did mathematics at school.

A 1 *Yz* hour written assessment consisting of 16 test items in mathematics was therefore administered at this point of the course. Trainees had been given notice of the 'test' and a revision syllabus some six weeks earlier. Their response to each question included a self-assessment of their ability to complete it successfully. The scripts were marked and the response to each question coded either: secure, possibly secure, not secure. The middle category was created in recognition of the difficulty (resolved later) of making confident inferences from some of the written responses. Corresponding scores of 2, 1 and 0 respectively were recorded for each question and each student were entered on a spreadsheet. In mid-February, an individual audit feedback sheet was returned to each student, with guidance (where appropriate) for further study.

39 students (about 25% of the cohort) who had been found to be secure in 15 or more of the 16 topics audited were invited to become mathematics peer tutors. Following training for this task, they conducted one-to-one peer tutoring sessions with all other students (on average, three per peer tutor) in April, writing a feedback sheet on each of their tutees.

TRAINEES' MATHEMATICAL THINKING

One dimension of our research is to identify what mathematics (within the remit of Circular 10/97) primary trainees' find difficult, and the nature of their errors and· misconceptions in theses areas. Facilities in the four 'easiest' and 'hardest' of the 16 items audited were as follows:

HIGHEST FACILITY		
% secure[1]	Mean score[2]	TOPIC
94	1.92	Ordering decimals
94	1.92	Inverse operations
90	1.86	Divide 4-digit number by 2-digit
89	1.85	Order fractions

LOWEST FACILITY		
% secure	Mean score	TOPIC
63	1.46	Generalisation
60	1.40	Pythagoras, area
43	1.17	Reasoning, argument
40	0.95	Scale factors, percentage increase

1 The written response gives a high level of assurance of the knowledge being audited 2 A secure response scores 2, which is therefore the maximum possible for the mean.

It is important to try to interpret some of these findings within the context of the course and the audit. For example, some standard errors and errors and misconceptions associated with ordering decimals are well-documented (Mason and Ruddock, 1986). For this very reason, these common difficulties are brought to the attention of trainees in the taught course, as an important detail of the professional knowledge they need to acquire. This may account for the subsequent low incidence of such mathematical errors in these trainees. For other topics, such as generalisation, the taught course appeared to have been less influential, or the topics themselves inherently more demanding. Others, such as Pythagoras' theorem, were not given detailed attention in the course.

Ongoing analysis of responses to the more difficult items is uncovering errors which illustrate a continuum of 'gaps' in trainees' subject knowledge in particular areas. By way of illustration, the 26 insecure responses to the following question (on generalis at ion) were scrutinised.

> Check that 3+4+5=3x4 8+9+10=3x9 29+30+31=3x30
>
> Write down a statement (in prose English) which generalises from these three examples. Express your generalisation using symbolic (algebraic) notation.

Responses were assigned to categories named (for example): blank, irrelevant, incoherent, checks but does not generalise, makes false generalisation. The last of these was perhaps the most interesting. The response of one student most clearly represented the 7 trainees who made one particular error:

"Three consecutive numbers added together equals the product of the first two numbers.

$n + (n+1) + (n+2) = n \times (n+1)$."

These responses appear to focus on the first example (3+4+5=3x4) to the exclusion of the other two, or to indicate inability to see the second two examples as counterexamples to the proposed generalisation. The '3' after the '=' is not perceived as the one constant term common to the three equations. It is perhaps not difficult to share the concern of the TT A about prospective primary school teachers who, for example, find it so difficult to perceive and communicate a 'one-ness' of form (let alone of meaning) in the three equations. It is also questionable whether the IT A's fondness for self-study (DfEE, 1997, p.27) is misplaced in the face of such cognitive obstacles.

SUBJECT KNOWLEDGE AND CLASSROOM PERFORMANCE

Research at King's College into effective teachers of numeracy suggests that what matters is

> .. , not formal qualifications or the amount of formal subject knowledge, but the nature of the knowledge about the subject that teachers have. (Askew *et al,* 1997, p. 93)

With this in mind, another strand of our enquiry investigates whether a significant link between subject knowledge, as measured by the audit, and students' performances on teaching practice can be identified. Given the King's findings, it might be expected that trainees' teaching practice performance would be independent from their audit of 'formal subject knowledge.

Method

Students were assigned to a 2-way classification:

I: Audit scores (maximum score being 32).

> Category A, B or C corresponding respectively to audit score above 30 (i.e. perfect or near-perfect), between 30 and 24, below 24 (of whom almost all were insecure on 3 or more items)

II: Teaching practice performance

> Students were categorised as I (very strong/strong), 2 (capable) or 3 (weak) on the basis of a formative grade profIle given on their first (Spring) term teaching practice for planning, teaching and assessment. It should be noted that these grades - the best available to us at the time of writing - do not relate solely to the teaching of mathematics.

These data are shown in the contingency table below, together with expected frequencies (in brackets) based on the null hypothesis that audit performance and teaching performance are independent.

	TEACHING PRACTICE PERFORMANCE			
SUBJECT KNOWLEDGE AUDIT		1 (strong)	2 (capable)	3 (weak)
	A (high)	**7 (5.6)**	**29 (27.4)**	**3 (6.1)**
	B (middle)	**12 (10.3)**	**49 (50.5)**	**11 (11.2)**
	C (low)	**3 (6.1)**	**30 (30.2)**	**10 (6.7)**

A chi-square test can be applied to these grouped audit and teaching practice data. The contingency table has 4 degrees of freedom, and $\chi^2 = 5.59$, with probability $p = 0.23$. Such a high probability supports the hypothesis that teaching practice performance and audit performance are independent.

Some 'extreme' cells may seem to cast doubt on this conclusion. For example, the actual number of C3 students is 50% more than 'expected'. Is then a low audit score, in particular, a significant predictor of weak teaching performance? Again, the answer must be 'no'. On the hypothesis that the distribution of the 43 students with low audit scores across the three teaching grades is the same as that for the whole population, a binomial model $B(43, {}^{24}/_{154})$ gives the probability of 10 or more category C3 trainees to be 0.12 i.e. not significant, even at the 10% level.

We are currently revisiting these questions, updating our data with grades specifically related to the teaching of *mathematics* in the final (Summer) teaching practice.

TRAINEES WITH SECURE MATHEMATICS SUBJECT KNOWLEDGE

A third dimension of our research concerns the histories, attitudes and professional trajectories of trainees who score highly against our audit oftheir 'formal' mathematics subject knowledge.

Sixteen students out of 154 were secure on all of the 16 audit items. 11 ofthese have A level mathematics (although another 16 with A level are represented throughout the 'top' two-thirds). Eight of the 16 have been selected for case study - four specialising in Early Years, four in Middle Years (KS2). Their degrees are in Psychology (4) English, Social Anthropology, Society and Technology, Linguistics and German. Four have A level mathematics. In the self-audit, all but one were *confident* about their own ability to teach the mathematics subject content of the audit to someone else. Here, we focus on the exception, an Early Years specialist whom we shall call Frances. A mature student, she has a 2.1 Cambridge degree in Social Anthropology, three A levels at A grade and a level grade 2 in mathematics. She is academically well qualified but not particularly so in mathematics.

A tension between her pedagogical knowledge and beliefs, and the practices she encountered in school was apparent in her first teaching practice. The class teacher taught mainly by using worksheets and this was not what the student wanted for her own teaching.

In a coursework essay, Frances reflected:

> 'In my own teaching practice there was a problem in laying the basis for progression. In the scheme of work agreed, I planned to teach the concept of difference, then show how it can be represented by the minus sign. However, when I team taught with the class teacher at the end of the practice, the teacher said she didn't like to teach subtraction as difference but only as 'take away' because it was confusing at this age.'

Grossman *et al* (1989) believe the task of transforming disciplinary knowledge into content suitable for students is one of the central skills of teaching. Frances argues:

> 'However, if teachers' understanding is deeper and the learning objectives are related to how the subtraction sign fits into the whole "form of discourse" (Aubrey, 1994), it is relevant to introduce the idea that a minus sign can mean different things to quite small children, especially once they are familiar with more than one subtraction structure.
>
> I was consciously using my knowledge both about mathematics, its nature and its concepts and my knowledge and experience about how young children learn. Presenting young children with

the concept of mathematical difference without linking it to their existing practical experience would have been akin to presenting them with a foreign language with no scope for translation.'

This points to Frances' own understanding, and how a student's thinking may be more theoretically sophisticated than that of the class teacher with whom they are training.

Frances was the only one of the group who was not confident about her ability to teach the subject matter of the audit, even though her 'test' result did indicate that her subject knowledge was highly secure. It is easier to make judgements about a lesson and how to extend children's understanding if the teacher is confident of their subject matter (Pollard *et al*, 1997). This factor underpinned a second tension for Frances, between what she believed to be best for pupils and her reluctance to implement it. Elsewhere in her writing, she recognises her *lack* of confidence

> 'To develop powers of reasoning, children need opportunities for mathematical investigation. In not capitalising on such opportunities, I failed to present mathematics as an investigative problem solving subject. This was an example of how use of subject knowledge can be affected by confidence and experience. At an intellectual level I appreciated the importance of mathematical investigation, but did not have the confidence to pursue it.

Frances is eloquent and reflective about her practice. She is aware of why she had problems but needs the confidence of experience to pursue her own ideas and work upon these. She illustrates why a high level of subject knowledge and understanding of pedagogy are clearly not enough because her problem is a lack of confidence in herself.

THE PEER TUTORING PROCESS

The peer tutoring arrangements have been the focus of our fourth research initiative. 32 students who scored highly in the subject knowledge audit agreed to act as peer tutors to other students, following a briefing session. These met with their tutees one-to-one, following a prearranged schedule of appointments, and reviewed the troublesome items in their tutee's subject knowledge audit paper. Out of 32 peer tutors, 18 agreed to audio-tape record the sessions. Of these, 15 persuaded at least one of their tutees to be tape-recorded. As a result we have several hours of recorded material that we are in the process of transcribing for analysis.

The peer-tutorials seemed highly-charged events for the participants. No doubt the negotiated audio taping contributed to this, but it seemed as if this extra dimension was insignificant compared with the self-consciousness engendered by the occasion itself. Most noticeable was the degree of controlled anxiety amongst the peer tutors. They felt their professional responsibilities keenly, notwithstanding their professed confidence; discussion with them on the day suggested that they had a strong sense that both their subject knowledge and their pedagogic skills were on the line. The material from the transcribed tape-recordings is very rich. The preliminary analysis is suggesting several themes that could be pursued.

For example, the material could be explored in terms of the range of discussion taking place around particular questions on the audit. The hierarchy of difficulty of the questions is such that much of the taped material focuses on a fairly narrow range of the more difficult topics (see the earlier table). Clearly some work on the data related to each question will be rewarding. By contrast there is a much smaller amount of material relating to the easier questions in the audit, and these are interesting cases because they tend to involve, as peer tutees, those students whose subject knowledge is apparently most seriously deficient as judged by our audit.

As teacher educators engaged on a day-to-day basis with making professional judgements about the effectiveness of the teaching of novice teachers, the most seductive aspects of a preliminary review of the material relates to the sense that some of the peer tutors are more effective teachers than others. This 'sense' requires a great deal of disciplined unpacking, but is informed, for example, by the contrast between the determination of some peer tutors to 'explain' and the willingness of others to listen. Follow-up work which invited peer tutors and/or tutees to evaluate the teaching and learning (with or without access to the taped record) would be an interesting project.

In addition, issues of tutor/tutee gender relations, of patterns in turn-taking and the exploration of many language issues are all potentially available. One of the most interesting features of this initiative is its particular context as an example of peer tutoring in the context of learning to teach. There is a long-standing interest in peer tutoring (Topping, 1996) but little work has been done on its potential within teacher education.

The relationship between subject knowledge and pedagogic knowledge is not a simple one (Shulman, 1987, McNamara, 1991), and through their participation in peer tutoring, students could be encouraged to confront and explore it. If this approach to addressing students' needs for enhanced subject knowledge proves fruitful, we could consider extending it through sensitive use of the taped material as part of the learning experience of the course.

We need to form a view about whether these peer tutoring methods have the potential to support the remediation of deficiencies in subject knowledge *and* to develop teaching skills, and if they do, how to refine and develop them.

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