Auditing Mathematical Subject Knowledge of Primary Teacher Trainees

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Abstract
This study focused on a series of audits of primary teacher trainees' mathematics subject knowledge. The audits were conducted at the beginning of each term of the trainees' primary postgraduate certificate of education programme, i.e. September, January and April. Background variables by which these data were analysed were trainees' academic grades in GCSE Mathematics. Preliminary analysis indicated that there were four areas of subject knowledge which trainees generally found difficult: equations, functions and graphs; reasoning and proof; shape and space; and algebra. Analysis further indicated that the degree of difficulty encountered by trainees corresponded with academic grades in GCSE Mathematics, i.e. Grade 'A' encountered the least difficulty, Grade 'B' encountered moderate difficulty, and Grade 'C' encountered the greatest difficulty. Further analysis of trainees with Grade 'C' indicated that those who had achieved the Grade 'C' in 1999 or before encountered less difficulty than trainees who had achieved Grade 'C' in 2000 or after. The implications of these findings are discussed.

Literature Review
All postgraduate students aspiring to achieve qualified status as primary teachers are expected to demonstrate their competences to be effective teachers of numeracy — concurrent with demonstrating competences in other elements of the primary curriculum — during programmes which are under heavy constraints of time (Haylock, 2002: 20). Concern has been expressed that, within the constraints of Primary Postgraduate Certificate of Education [PGCE] programmes, greater priority should be given to subject knowledge of mathematics, even though this would be at the expense of other elements (Rowland et al, 2003: 95). Most recently, the Interim Report of the Review of Mathematics Teaching in Early Years Settings and Primary Schools (DCSF, 2008) — the Williams Review — has noted that:

‘other competing demands on the trainees’ time then imply that, on most PGCE courses, the amount of learning devoted specifically to mathematics is between 10 to 15 days at most… It is fair to observe that this can be expected to bring about little change in the mathematical competence and subject knowledge of a trainee whose previous background in mathematics extends simply to a grade ‘C’ at GCSE” (ibid.: p. 20, para.21).

The recommendation of the Williams Review is that the potential for entry to a Primary PGCE being conditional on the achievement of grade ‘C’ in both
Mathematics I and II GCSE should be considered. However, until such time as Mathematics I and II GCSEs are established, grade ‘C’ at GCSE will remain the requirement.

Given the current circumstances, all Primary Initial Teacher Training [ITT] programmes should “have in place strategies to audit, develop and assess student teachers’ mathematical subject knowledge” (ibid.: para. 22). Hansen (2008: 2) remarks that — by posing the question ‘Do I really need good subject knowledge to teach mathematics well?’ — an ITT programme should focus trainee teachers’ attention on the Professional Standards for teachers (TDA, 2007). One intention is to ensure that trainees, on completion of ITT programmes, will be emancipated from dependence on mathematics schemes, as Harries and Barrington (2001) remarked the tendency in many schools:

“to use a scheme as the mathematics curriculum rather than a resource which helped to deliver the mathematics curriculum” (ibid.: 19).

Mooney et al (2007: 3) contend that “healthy subject knowledge of mathematics” is “a critical factor in the complex process of teaching mathematics”. Trainees’ mathematics subject knowledge, in effect, will provide resources upon which the trainee will draw when planning and teaching “whether intentionally or spontaneously in the course of interaction with pupils” (Goulding et al, 2002: 702). Development of mathematics subject knowledge should ensure that mathematics is “generated rather than merely administered in the classroom” (Brown et al, 1999: 319). As Haylock (2006: ix), in his final lecture before retiring, told his PGCE students, “the most important thing he had learnt about teaching” was that:

“the best teachers are those who have a secure personal understanding of the structure and principles of what they are teaching.”

The small-scale study reported concerns audits of primary teacher trainees’ subject knowledge of mathematics, and the effects of subject knowledge support on their development of subject knowledge in mathematics.

Methodology
Participants in the study were teacher trainees on a postgraduate certificate of education [PGCE] programme for primary sector. These trainees included 191 trainees with GCSE Mathematics, grades A-C:

• 28 trainees with grade A;
• 90 trainees with grade B; and
• 73 trainees with grade C.

Trainees’ subject knowledge of Mathematics was audited on entry to the PGCE programme — September 2007 — but this audit was sent to trainees before the start of the programme and readings to support the development of their subject knowledge were suggested.
Subsequently, for those trainees who failed the audit on entry, four Mathematics subject knowledge support sessions were provided. Sessions were complemented by the provision of support materials. The sessions and materials in 2007/8 covered the relevant subject knowledge of algebra, equations, functions and graphs, reasoning and proof, and shape and space.

Subsequently, subject knowledge of Mathematics was audited in January and April 2008.

**Findings**

The data provided by the three audits are reported for 191 trainees and for sub-samples of trainees categorised by their prior GCSE Mathematics grades, i.e. A, B and C.

All trainees’ performances on the three audits of Mathematics subject knowledge are reported in Table 1. The raw figures represent the number of trainees who did not pass, and these figures are also presented as proportions of all trainees.

**Table 1: All Trainees’ Performances on Three Audits of Mathematics Subject Knowledge**

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<thead>
<tr>
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<tr>
<td>Number System</td>
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<td>2</td>
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<td>.005</td>
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<td>.351</td>
<td>19</td>
<td>.099</td>
<td>8</td>
<td>.040</td>
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<tr>
<td>Equations, functions &amp; graphs</td>
<td>87</td>
<td>.455</td>
<td>40</td>
<td>.210</td>
<td>18</td>
<td>.090</td>
</tr>
<tr>
<td>Reasoning and proof</td>
<td>110</td>
<td>.576</td>
<td>14</td>
<td>.073</td>
<td>9</td>
<td>.045</td>
</tr>
<tr>
<td>Measures</td>
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<td>.052</td>
<td>0</td>
<td>-</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>Shape and space</td>
<td>82</td>
<td>.429</td>
<td>17</td>
<td>.089</td>
<td>9</td>
<td>.045</td>
</tr>
<tr>
<td>Probability and statistics</td>
<td>26</td>
<td>.136</td>
<td>0</td>
<td>-</td>
<td>0</td>
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</tr>
</tbody>
</table>

The data disclosed that there were four areas that trainees found difficult throughout the three audits: reasoning and proof; equations, functions and graphs; shape and space; and algebra.

Further analysis of mathematics subject knowledge was undertaken by sub-samples of trainees by the grades achieved at GCSE, i.e. ‘A’, ‘B’ and ‘C’. The nine areas of mathematics subject knowledge were conflated for this analysis.

**Table 2: Performance of Trainees with GCSE Maths Grade ‘A’, ‘B’ and ‘C’ on Three Audits of Mathematics Subject Knowledge**
Analysis of these data disclosed that trainees’ performance on the three audits corresponded with the grades that the trainees had achieved on GCSE Maths. Those trainees with an ‘A’ grade failed fewest areas relative to other trainees. The performance of trainees with an ‘A’ grade was taken as a baseline for comparisons with other trainees:

- trainees with a ‘B’ grade failed five times as many areas on the September audit, and four times as many areas on the January audit and April audit; and
- trainees with a ‘C’ grade failed six times as many areas on the September audit, almost nine times as many areas on the January audit, and thirteen times as many areas on the April audit.

Thus, while trainees with a ‘B’ grade ‘catch up’ with trainees with an ‘A’ grade across the three audits, trainees with a ‘C’ grade may improve but they fall further behind trainees with an ‘A’ grade and trainees with a ‘B’ grade across the three audits.

Further analysis was undertaken of mathematics subject knowledge by sub-samples of trainees who achieved grade ‘C’ at GCSE in 1999 or before and in 2000 or after. The nine areas of mathematics subject knowledge were conflated for this analysis.

### Table 3: Performance of Trainees with GCSE Maths Grade ‘C’ on Three Audits of Mathematics Subject Knowledge

<table>
<thead>
<tr>
<th>Trainees’ with GCSE Maths Grade ‘C’ by Years</th>
<th>Total Areas of Subject Knowledge Failed</th>
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<tbody>
<tr>
<td></td>
<td>Sept. Audit Raw</td>
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<tr>
<td></td>
<td>Proportion</td>
</tr>
<tr>
<td>1999 or before [n = 32]</td>
<td>97 .337</td>
</tr>
<tr>
<td>2000 or after [n = 41]</td>
<td>128 .347</td>
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</table>

Analysis of these data disclosed that trainees’ performance on the three audits demonstrated some correspondence with the year in which the trainees had achieved GCSE Maths grade ‘C’. While similar proportions of areas of subject knowledge were failed by both sub-samples of trainees in September, those trainees who had taken their GCSE in 1999 or before failed fewer areas in the January and April audit than those trainees who had taken their GCSE in 2000 or after.
Discussion

The Primary PGCE mathematics team at the University of East London have, for many years, focused on the mathematics subject knowledge of our trainees. We have audited, tracked and supported trainees in the development of their mathematics subject knowledge before and during the PGCE programme. The present audit of trainees’ subject knowledge has been in use since 1999 and has provided information relating to different areas of mathematics. Since 2005, trainees have been sent the audit prior to starting the programme. The provision for trainees has included support sessions at UEL, suggested readings and websites, and peer support in the form of study groups. More recently, we have been considering how to further support trainees once they have been offered a place on the programme and whilst they are on the programme. This could include some form of individual training plan which would address, amongst other things, their mathematics subject knowledge.

The audit process was very stressful for the trainees and, for some, this stress was increased as they tried to see the links between their own subject knowledge and the primary mathematics curriculum. The pass mark for each area of mathematics (number system; indices; number operations; algebra; equations, functions and graphs; shape and space; probability and statistics) was half marks and above. Those trainees who passed were encouraged to continue to develop their subject knowledge. All trainees were required to keep a subject knowledge audit and self-study file with sections to address each area of the mathematics audit. The file comprised several elements: a copy of their audit record sheet with targets updated as required; study notes from recommended references; notes from taught sessions; annotated downloads from websites; completed quizzes; and corrections and re-tests from the original audit.

Those trainees that did not achieve a pass mark on a section of the audit were required to resit that section at the next opportunity, i.e. in the next term. For those trainees whose subject knowledge still needed to be audited, this stress was undoubtedly intensified.

Analyses of the audit data would indicate that there was a correspondence between trainees’ GCSE Mathematics grade and the areas of Subject Knowledge failed during the three audits.

Those trainees who had achieved Grade ‘A’ in GCSE Mathematics failed few areas of Subject Knowledge (see Table 2): these students failed, respectively, .056, .012 and .004 of areas in September, January, and April. Only one area was failed by one student (of 28 students) in the April audit.

Those trainees who had achieved Grade ‘B’ in GCSE Mathematics, by comparison, failed a greater number of areas: these students failed, respectively, .306, .048 and .017 in September, January and April (see Table 2). The student fail rate, from September to January, was reduced to a sixth and, from January to April, was reduced to almost a third: overall a reduction to an eighteenth from September to April.
Those trainees who had achieved Grade ‘C’ in GCSE Mathematics, by comparison, failed the greatest number of areas: these students failed, respectively, .342, .102 and .052 in September, January and April (see Table 2). The student fail rate, from September to January, was reduced to under a third and, from January to April, was reduced to almost a half: overall a reduction to almost a seventh from September to April.

Clearly, four areas posed problems for trainees: algebra; equations functions and graphs; reasoning and proof; and shape and space. Solving linear and simultaneous equations and representing functions graphically and algebraically were areas that many trainees found challenging. Concerning shape and space, describing the transformation of a shape was something many trainees could not complete fully. Concerning reasoning and proof, many trainees had some knowledge of different proofs — deductive, exhaustive and disproof by counter example — but could not show how the proof could be applied. One of the taught sessions of the programme specifically concentrated on standard methods of proof.

At UEL we will continue to audit and track trainees’ mathematics subject knowledge. In terms of support we are considering testing candidates at interview so that, if they were successful in gaining a place on the programme, they could have specific guidance on the areas of mathematics that they needed to develop. We are also considering for the taught PGCE programme, in light of the Williams Review, as to how trainees may be best supported to develop their mathematics subject knowledge. The number of taught sessions may have to increase and the type of support may have to include specific revision on UEL’s internal web pages. The challenges will be to further identify those areas of mathematics that need support and development and to address each trainee’s needs, so that our teachers of the future have secure mathematics subject knowledge.

References

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