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PRIMARY TEACHER TRAINEES' MATHEMATICS SUBJECT KNOWLEDGE - PROGRESS IN DEVELOPING SYSTEMS OF SUPPORT?

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INTRODUCTION

As a matter of course, primary teacher trainees are introduced to theories of learning and to a range of pedagogical approaches as part of their training for teaching. From the outset they are encouraged to become aware of their own learning processes - a focus on meta-cognition - and share insights with their peers, and to do so in a way that might inform their teaching of children.

The role of social interaction and collaboration in learning are explored. In their classrooms, trainees are encouraged to try a range of pedagogical approaches as they learn their craft, including setting up situations in which their pupils are encouraged to think about their own learning, can collaborate and help each other to learn.

It is a basic premise that in our own approaches as teacher educators within initial teacher training that we should aim to demonstrate these processes in our own teaching. At the Institute of Education we have been trying to encouraging collaborative learning amongst our trainees and trying to judge where collaborative approaches might be most effective.

In recent years we have been developing a place for peer tutoring within the learning experiences for trainee teachers within the PGCE course, and it is in relation to the development of curriculum subject knowledge that peer tutoring is now most formalised.

In each of the curriculum subject areas where, until recently, there has been a requirement to audit the subject knowledge of trainees and take steps to remedy any deficiencies (DfEE 1998) we have developed course structures that include a role for peer tutoring.

This paper describes our approaches to subject knowledge development in Mathematics and the role of peer tutoring within it.

In collaboration with researchers in the universities of Cambridge, Durham and York (see also e.g. Goulding, 2002; Huckstep, Rowland and Thwaites, 2002) under the acronym SKIMA (subject knowledge in mathematics) we have been exploring aspects of trainees' subject knowledge. This paper describes a small scale review of feedback to us from peer tutees and peer tutors from the 2001 - 2002 cohort of trainees at the Institute of Education.

PEER TUTORING

Reviewing the literature related to peer tutoring is handicapped by the wide range of names by which its variants are known, some of them akin to 'brand names' (Falchikov, 2001). The concept of a 'peer' is also debated. Topping suggests peer tutoring involves 'people from similar social groupings who are not professional teachers helping each other to learn and learning themselves by teaching'. (Topping in Goodlad 1998, p.50) This definition draws attention to the assumption that there is potential for *both* parties to learn from the experience of peer tutoring.

Teacher trainees meet Topping's definition in that they are not 'professional teachers', yet this is precisely what they aspire to be in due course - so, it might be argued that this gives peer tutoring in this context a special potential and a special interest.

In his review of the literature about peer tutoring within Higher Education contexts, Topping points out that there is a great deal more research into teaching and learning in schools than in Higher Education settings (Topping in Goodlad 1998). Similarly much of the work on the contribution of peer tutoring processes to learning has taken place in school settings.

Much less is known about adult learning - yet there is increasing scrutiny of the effectiveness of teaching and learning in tertiary settings. Topping suggests, with a certain irony, that the upsurge in interest in peer tutoring in Higher Education may be a pragmatic response to the double bind in which these institutions find themselves. Shrinking resources push them back towards traditional instructional methods, yet these are consistently criticised as ineffective. Including elements of peer tutoring may offer a way out of this difficulty.

More optimistically, it seems that the majority of research studies that attempt to evaluate peer tutoring initiatives do suggest that peer tutoring has a positive effect. Some of these involve control groups and the independent measure of learning gains in different conditions, and some rely only on outcomes reported by participants. 'Studies of achievement gains almost all indicate outcomes as good or better than group tutoring by faculty, and student subjective feedback is generally very positive.' (Topping in Goodlad, 1998, p. 67)

Most commentators distinguish different kinds of peer tutoring. Topping suggests a typology for peer tutoring in Higher Education settings. Peer tutoring schemes can vary by curriculum content, contact constellation, year of study, ability, role continuity, place, time, tutee characteristics, tutor characteristics and by objectives.

He surveys a range of types that do not seem to be mutually exclusive. For instance:

- Cross-year small group tutoring
- The Personalised System of Instruction (PSI) - this is a system of peer monitoring, checking and assessment, based on structured materials
- Supplemental Instruction - this refers to peer assisted learning of study skills with an element of peer counselling - emphasis on process rather than product
- Same-year dyadic fixed-role tutoring
- Same-year dyadic reciprocal peer tutoring

- Dyadic cross-year fixed role peer tutoring
- Same-year group tutoring
- Peer assisted writing
- Peer assisted distance learning

The type of peer tutoring under consideration here is same year dyadic fixed role tutoring.

In reviewing the literature across the types, 'same-year dyadic fixed-role tutoring and peer assisted writing have shown considerable but not necessarily consistent promise and should be the focus of continuing experimentation and more research of better quality' (Topping in Goodlad, 1998, p 68).

The exhortation to 'better quality' is chastening. Our study is modest in scope and aspires not to making any great contribution to the general field but to developing our own professional practice in a positive way.

One very striking aspect of the reviews of peer tutoring initiatives that we have found so far is how little attention has been given to differences in the 'material' to be learned - the 'curriculum content' aspect of Topping's typology. Some of the work reported has made the distinction between personal/social development goals and academic goals, and in those projects concentrating on academic goals, reference has been made to a subject focus - substantial proportions of the work reported seem to come from undergraduate psychology, engineering, science and mathematics. However little attention seems to have been given to any distinction that can be drawn between knowledge and skill or between a model that refers to 'mastering the material' and being able to apply it. Then, in addition, in our context of initial teacher education, the mastery of 'subject knowledge' carries with it the idea of subject knowledge *for* teaching (**Askew??)** and recent discussions of the relation between subject matter knowledge and pedagogical content knowledge become relevant (Shulman, 1986; Huckstep, Rowland and Thwaites, 2002).

We have found few references (so far) to peer tutoring in the context of initial teacher training.

MATHEMATICS SUBJECT KNOWLEDGE DEVELOPMENT - OUR CONTEXT

At the start of the Mathematics component in the first term of the PGCE at the Institute of education, trainees complete a self audit of their Mathematics subject knowledge. The self audit consists of a 21 item Mathematics 'test' including items designed to cover the areas in the Mathematics subject knowledge requirements (DfEE 1998). Trainees are asked for solutions and in the case of some items to show and explain how they did it. They are then asked to make a judgement about their success in approaching each item. They are asked to work through this audit in their own time, to 'mark' it themselves using a commentary that we give to them and to complete a feedback form for the tutor team. An analysis of the responses to the self audit and of the self report form another part of our research across the three training institutions (Goulding 2002).

The data from this process is entered on a spread sheet so that an analysis across the whole cohort is possible. This alerts us to levels of confidence and the relative perceived 'difficulty' of items across the range. Personal tutors are given a picture of the results so that they are able to see how the trainees for whom they have responsibility have fared. This is the first stage in a process of Mathematics subject knowledge enhancement to which all trainees are encouraged to commit. On the basis of the information from the feedback personal tutors encourage trainees to choose and use a range of strategies for developing their subject knowledge including self study and peer tutoring. This is a relatively informal process and there is wide variety in the way in which trainees take it up. We know, however, that some trainees use peer tutoring at this stage and there have been many examples of one to one and small group tutoring.

In February trainees complete a second 'unseen' audit under supervision. This audit covers the same ground as the initial self-audit but using different items. Trainees are given a sheet with common formulae and are permitted one page of their own preparatory notes. This audit is marked by the teaching team using a marking scheme which had been developed and agreed by the research group for use across the three institutions).

On the basis of the results of this audit the trainees' scores are ranked and formal peer tutoring arrangements are set up by the teaching team. The highest scorers (this year the top 10%) were invited to act as peer tutors and attended one taught session (training?) to prepare them for their role. The nature of this preparation is discussed below. The lowest scorers (bottom 10%) were offered peer tutoring and attended one taught session as a group preparatory to this. The highest scorers were matched one-to-one with the lowest scorers and these dyads meet on one occasion only in order to review the audit items that caused difficulty to the peer tutee.

The 'middle' group had an occasion set aside during which they were encouraged to work in groups on any items which caused difficulty.

All trainees were asked to complete a feedback sheet reflecting on this process and it is this data which mainly provides the basis of our analysis.

METHODOLOGY

We have used three sources of data overall. We were interested to see to what extent the trainees who scored most poorly in the formal audit, identified themselves in the initial self audit. We returned to the 'self reports' of this group and analysed them using the categories generated by Goulding (2002) from the whole sample across three institutions. We carried out interviews with the staff who had taught the preparatory sessions for the peer tutors and the peer tutees and finally we analysed the written feedback provided by both groups after the peer tutoring session had taken place.

PEER TUTEES' INITIAL SELF REPORT

Trainees were asked to rate their response to each self audit item using the following scale:

0 I couldn't begin this question without help
1 I attempted this item, but didn't make much progress
2 I made some progress but with significant errors and omissions
3 My response was basically secure, with only minor errors and omissions
4 My response was basically secure

They were also given the opportunity to add any further comments.

Goulding's nine categories for analysing these further comments are shown below:

Category	Description
A	Level of confidence
B	Assessment of knowledge
C	Self audit process
D	Help used
E	Remedial process
F	Approaches to learning
G	Miscellaneous
H	Specific areas of difficulty
J	Generic difficulties

The analysis of the comments made by the peer tutees (n=20) shows that the general level of confidence was low with many reporting panic.

'I tend to freeze when I am required to do maths'.

They also perceived their levels of knowledge as low and many said they had forgotten the mathematics they had previously learned.

'My maths seems very rusty and I need a lot of time to recall back to different methods of calculating things.'

They generally found the process of the audit very difficult. Only one trainee reported feeling fairly happy and one other said that she was aware of some of the required procedures. Some trainees suggested that the remedy for the poor state of their subject knowledge was self study and lots of revision of the forgotten topics. They felt they needed lots of practice.

'I recognise that I need to do self study in order to refresh my memory'.

However, since these trainees subsequently scored in the bottom 10% in the formal audit four months later, it does seem that the self study strategy (and indeed the taught mathematics course) was not sufficient.

Specific aspects of mathematics that were identified as causing particular difficulty included algebra, forgotten formulae, visualisation, long division, space and shape, and measures.

'The questions I had the most problems with were the questions that required me to express numbers into algebra'.

This difficulty with algebra was widespread in this group and so algebra was a special focus in the preparatory sessions for peer tutoring provided by members of our teaching team.

The generic difficulties reported included taking a long time, not knowing where to start, knowing methods but not remembering how to apply them, not understanding the question and forgetting procedures.

'On some questions I didn't know where to start. This scared me – just how bad is my maths?!'

Finally several trainees referred to the process of the initial self audit as helpful with its supporting commentary.

'My subject knowledge does need work as I have forgotten much of what I did at GCSE. However, this audit has helped me realise what I need to work on'.

PREPARATION FOR PEER TUTORING

The interviews with the tutors who provided the preparatory sessions took place after the teaching and explored the perceptions of those colleagues of the teaching and learning that had taken place.

Teresa worked with the peer tutees and set herself the task of helping them in relation to
the most problematic questions, which were the ones involving algebra but also hoped to improve their general strategies for approaching similar questions and raise their levels of confidence.

She took questions from the audit paper substituting different values. Through a process of first looking at an example together and then working in groups on similar ones, and then coming back together, they were able to work towards a generalisation.

Throughout the process Teresa tried to push the trainees to think about what was happening and to describe it in 'longspeak'. Descriptions were then shortened and refined. A trainee then identified it as 'proper algebra'. Teresa was deliberately using a process that she would use with children and she encouraged the trainees to recognise this. They reported to her that they found it liberating to be asked to describe operations in words as they would in writing an essay. Answers were checked using calculators. Problems were then extended to make them more challenging. This process of group work followed by whole class discussion to consider processes and solutions continued over the range of the items with which they had experienced most difficulty.

Teresa felt that a very positive aspect of the session was that the trainees were willing to make mistakes publicly. Others were encouraged to pick up on the mistakes. They talked about questions they had been asking themselves and others that Teresa had posed. This was a process of internalisation. They discussed ways of coping with algebra without panicking. They gradually articulated a series of strategies that would help them but not a recipe.

Some trainees explained that algebra was new to them - their mathematics qualification had been achieved through an 'access' route or had been GCSE at a low tier so that algebra was not included. The only time they recalled tackling problems of this sort had been during the PGCE course and in big groups which they did not find helpful. They seemed to enjoy the experience of working together.

It seemed that this group situation had changed attitudes as they had thought they were 'stupid' but they had really benefited from and enjoyed the session with Teresa.

Later one tutee wrote, *'The session with Teresa was very good. She presented the maths we had problems with in such an unthreatening way, which in turn built up my confidence in the areas of algebra. She's brilliant.'*

The peer tutors worked with Amy who also concentrated on the audit items that had caused the most difficulties for the peer tutees. Taking each item in turn, Amy asked the peer tutors to work in small groups going over it again, listening to eachother's explanations, then finally giving one person the opportunity to 'teach' the whole group. The peer tutors reported how enlightening it was to hear so many alternative ways of approaching each problem and how instructive to realise that their own perspective on the problem was not the only one.

During the preparatory session and during informal discussions with the peer tutors after the tutoring session it was clear that the peer tutors treated the responsibility with great seriousness. Generally they confirmed the impression gained from previous cohorts that they felt that not only their own subject knowledge but their pedagogic content knowledge were on the line. Many expressed apprehension at the prospect of the tutoring session and expressed doubts about what they had to offer.

FEEDBACK FROM THE PEER TUTORING EXPERIENCE - THE PEER TUTORS

The written feedback that the peer tutors provided after the tutoring session was analysed. Since the group was small (n=17) the quantity of data was not great. Categories for analysis were derived from the raw data and refined during the process of analysis. The following categories emerged and accounted for almost all of the responses.

After the event, the responses from the peer tutors were overwhelmingly positive about the experience. Even when responding to the invitation to comment on the 'most difficult' aspect(s) of the tutor role many peer tutors referred back to perceived deficiencies in their own subject knowledge but often explained how they had tackled these difficulties.

Confidence - their own and that of tutee

Some students wrote about their lack of confidence in their own subject knowledge and consequent doubt about their capacity to help; however many (and some of the *same* tutors) said that the experience had raised their confidence.

Satisfactions gained from 'helping'

'I was making a difference by helping my peers'

'most rewarding was the fact that I was able to give one-to-one support to a fellow student'

Aspects of mathematical content

'explaining rotation transformations is very difficult!'

Aspects of the teaching function - links to classroom pedagogy

'I found it difficult to explain some concepts at the right level…it sometimes helped to relate it directly to how I might teach the topic to children'

'Difficult to find different ways of explaining the same thing'

(Rewarding to have)… the chance to work with another adult (as opposed to a child) gave me more experience of how people learn'

'It improved my teaching skills'

'made me think about how to break a question down into steps and explain the jumps between them'

Subject knowledge gains - their own and that of the tutee

'I found the experience rewarding as it helped me to clarify many mathematical ideas in my own mind'

'My subject knowledge improved - especially enlargements which I got wrong on the audit'

'Explaining to another student helped me clarify my subject knowledge'

Aspects of the tutor/tutee relationship

'I hope it wasn't intimidating for my tutee - it didn't appear to be as we were both laughing!'

'I was glad it was someone from my cluster who I knew'

FEEDBACK FROM THE PEER TUTORING EXPERIENCE - THE PEER TUTEES

The categories generated by this analysis were 'usefulness', 'feelings', 'confidence', 'experiences', 'mathematics', and 'strategies'. The categorisation of the student comments (n=20) arose from the data itself, and the coding relied on interpretations which were checked during the process.

The questions they were invited to answer were ‘How did you find the experience of working on mathematics with a peer ?’ and ‘Which approaches or strategies adopted by your peer tutor did you find a) most helpful b) least helpful ?'

How did you find the experience of working on mathematics with a peer ?

All the peer tutees found that it was a helpful experience with many finding it was extremely beneficial.

‘I found working with a peer tutor extremely helpful. A lot of problems I had were clarified’.

Their feelings were comfortable and relaxed, preferring the one to one situation.

‘It was good to talk to someone else about difficulties and get advice from them.’

Confidence was much improved, too.

‘I found working with my peer tutor I felt less self conscious about where the gaps in my knowledge lie. Being able to work at a pace that was suitable for me to internalise the knowledge was very helpful.’

The experience was pitched right. It made remembering easier.

‘It was good to work at my own pace working through examples and explaining misunderstandings.’

Mathematics topics specifically mentioned were algebraic questions, ratio, rotational symmetry, proof and Pythagoras.

‘I now feel more confident in dealing with algebra, my peer tutor explained this in a simplified way that felt less threatening than using the algebraic terms in the audit.’

Which approaches or strategies adopted by your peer tutor did you find a) most helpful b) least helpful?

a) Strategies that helped included rephrased questions, demonstrations, systematic approaches, explaining to the tutor, relevant examples to apply knowledge, writing things down, picking the question apart, and visualisation strategies.

'A lot of the problems were to do with the language in questions and my peer tutor rephrased these and demonstrated certain questions to me such as the graph problem.'

b) Least helpful was where the peer tutor couldn't explain the algebraic questions. One trainee asked to visualise said they couldn't do it and another found the understanding of 'mathspeak' hard. However the majority did not identify any strategies as unhelpful.

'I found nothing unhelpful. It is a very good way of teaching and learning.'

General comments included *'I think this is a very good idea (peer tutoring) by the IoE and I feel that future students will also benefit from this provision, too.'*

'The experience was really helpful I feel so much better.'

DISCUSSION

Our aim, in reflecting on our experience and in undertaking this analysis of the perceptions of peer tutoring has been to seek to improve the effectiveness of our strategies for supporting our trainees. A number of issues have arisen as a result of this work.

If we are to support the trainees with weaker subject knowledge more effectively we need to provide ongoing support earlier in the course. This was highlighted in the self audit feedback, and also in Teresa's session, with many peer tutees reporting that they knew their levels of knowledge were poor. We need to pick up those who are finding difficulty and put in place more one to one and taught group sessions. However, early identification using the self audit only would fail to pick up some of the group, as only 50% of the eventual peer tutees were among the lowest scorers on the self audit, and some of those who were not, marked themselves as reasonably secure. They did, however, indicate their difficulties on the 'confidence' section of the self audit. One strategy we are considering is to ask trainees to indicate if they would like more support through peer tutoring at an early stage in the course. Falchikov (2001) discusses the challenge of ensuring that peer tutoring is embedded firmly in the culture of the course. This is a challenge for us too. Although at present the peer tutoring occasion is organised and orchestrated by staff and is part of the timetable of the course, it is only on a single occasion. Given the positive feedback, we are actively considering the way we support peer tutoring at earlier stages.

Many commentators suggest that appropriate training for peer tutors is a key issue in improving effectiveness (Falchikov, 2001). Although great appreciation was expressed for the preparatory sessions that were provided, we might consider whether, and in what ways, these might usefully be extended. If the use of peer tutoring were to be more formalised earlier in the course then perhaps a different approach to training would have to be devised.

'Quality control' in peer tutoring sessions would also be an issue - and it is hard to see how this could be secured. It is a considerable challenge for staff to monitor peer tutoring processes. Some studies suggest that peer tutoring is most successful where

the 'gap' between peer tutor and peer tutee is fairly narrow. This suggests that a different approach to organising pairings in our context might usefully be explored. Also pairings in which tutor and tutee change roles (rather than 'fixed' role pairings) are sometimes recommended. It is interesting to note that, although our research has not explored to any great extent the experiences of the 'middle' band of out trainees, we know that they were less enthusiastic about their experience of peer tutoring in more homogenous groups. There may be many reasons for this. Certainly the occasion was orchestrated very differently, and it may be that with different 'preparation', these trainees could gain more from the experience. We continue to think about this.

At any rate, self study as an approach to remedying deficiencies in mathematics subject knowledge does not seem to be sufficient. Many of the tutees, realising their low levels of subject knowledge early in the course, indicate that they will revise and use self study guides. However, the effectiveness of this may be limited. Half of those who identified themselves as having poor subject knowledge at the beginning of the course achieved the lowest scores in the formal audit. It may be that to develop knowledge and understanding in Mathematics requires more one to one support and guided teaching? We need to understand more about the role of peer tutoring in mathematics specifically.

Difficulties with algebra were a marked feature of this year's peer tutees. Some of the trainees have had no teaching of algebra in the past so we need to be aware of this and identify this group. We plan to revise our programme so that early sessions on problem-solving are differentiated and to adopt some of the teaching strategies used by Teresa to which the tutees responded so positively and to make more links to teaching in school. Some students did not know where to start with the audit questions. Strategies for starting and extending problem solving would be helpful from early on. Identified as reasoning and proof, Goulding (2002) says, ‘We would argue that the items on reasoning and proof in the audit demanded very little technical expertise but they did require the ability and willingness to investigate a situation, look for general patterns, make conjectures and try to justify them i.e. expertise in syntactic knowledge’.

After the Mathematics course input, subject knowledge input and the peer tutoring, all the tutees felt more successful. Several asked informally for ways to ‘prove’ their new knowledge. They were referred back to the self audit with the suggestion that they might work through it again and alerted to the presence of practice examples in the self study guides. However perhaps we should consider putting together banks of examples of our own or even a further audit paper for those who request it. We are aware that our study, in focusing only on the perceptions of trainees, casts no light on the question of whether the peer tutoring process leads to any subject knowledge gains. A different pattern of auditing might make this more possible.

The range of strategies employed by the peer tutors were welcomed by the tutees except for the trainee who found visualisation difficult and another where the tutor's explanation of algebra was not helpful. These issues might be addressed by making sure that we place more emphasis on the sharing of strategies in the taught sessions and in the preparation for peer tutoring.

Another interesting paper exploring a strategy for attempting to improve subject matter knowledge through peer tutoring. There were some striking issues, again, relating to lack of confidence in their own mathematics – even amongst those relatively successful ones doing the tutoring. There was also, for me, the issue of teaching strategies adopted. The tutors commented on their own opportunities to sharpen their thinking through *explaining* to the tutee. The tutees apparently found *explaining* to the tutor helpful. So *explaining* seems to be valued by everyone. But intriguingly, there was no mention of *listening* – something I would have loved to have heard the tutors commenting on. *e.g. it was hard to listen and then respond usefully to what the tutee said.* Or, *it was great that the tutor listened to my problems and could make links with what I knew.* OK, wishful thinking – but it raises for me the link with pedagogical content knowledge and the kinds of issues we might want to raise in early briefing sessions.

CONCLUSION

This small study, carried out without the benefit of funding, has probably done no more than sensitise us to some of the issues surrounding the development of subject knowledge in mathematics and the potential of peer tutoring as a strategy. Our training course deploys peer tutoring across a range of curriculum subject areas and we realise how little we know about how it works. There is plenty more to do.

References

Huckstep, P., Rowland, T. and Thwaites, A. (2002) 'Primary teachers' mathematics content knowledge: what does it look like in the classroom?' Unpublished symposium paper BERA Annual Conference at the University of Exeter 2002.

Askew, M. (2001) 'British Research into Pedagogy' in Askew, M. and Brown, M. (2001) *Teaching and Learning Primary Numeracy: Policy, Practice and Effectiveness*. British Educational Research Association.

Department for Education and Employment (1998) *Teaching, High Status, High Standards: Circular 4/98.* London: Her Majesty's Stationery Office.

Dong, Y. (1997) 'Collective reflection: using peer response to dialogue journals in teacher education', *TESOL Journal* , 7, 2: 26-31.

Falchikov, N. (2001) *Learning Together*. London: RoutledgeFalmer.

Goulding, M, Rowland, T and Barber, P (2002) Does it Matter? Primary Teacher Trainees' Subject Knowledge in Mathematics, British Education Research Journal, 28 (5) (in press)

Goulding, M. and Suggate, J. (2001) Opening a can of worms: investigating primary teachers' subject knowledge in mathematics. *Mathematics Education Review,* 13, pp. 41-54.

Goulding, M. (2002) 'Primary Teacher Trainees' Self Assessment of their Mathematical Subject Knowledge'. Unpublished symposium paper presented at BERA Annual Conference at the University of Exeter 2002.

Goodlad, S (Ed.) (1998) *Mentoring and Tutoring by Students*. London: Kogan Page Ltd.

Nattiv, A., Winitzky, N. and Drickey, R. (1991) 'Using cooperative learning with preservice elementary and secondary education students', *Journal of Teacher Education*, May-June, 42, 3: 216-25.

Rogoff, B. (1990) *Apprenticeship in Thinking: Cognitive Development in Social Context*. Oxford: Oxford University Press.

Shulman, L. (1986) 'Those who understand, knowledge growth in teaching'. *Educational Researcher* 15(2), pp 4-14.