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ICT, Mathematics and effective teaching

Rod Bramald, Jen Miller and Steve Higgins University of Newcastle upon Tyne

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This paper reports some aspects of the findings from a substantial project funded by the Teacher Training Agency. The project aimed to investigate effective pedagogy in numeracy and literacy using ICT in primary schools. Some preliminary findings relating to pupils' attainment and a series of lesson observations are reported. Some of the broader findings from the development work in mathematics and ICT are also discussed in the context of two particular case studies that focused on developing effective pedagogy in mathematics.

Introduction

This paper describes some aspects of a two year project investigating effective pedagogy in numeracy and literacy in primary schools (for 4-11 years olds) in England. The research was funded by the Teacher Training Agency (TTA), the government body responsible for the initial teacher training curriculum, standards and continuing professional development of teachers. The final report of the project has recently been published and contains more detailed information about the research and its broader findings (Moseley, Higgins et al. 1999). Some of the implications from specific parts are discussed here, particularly in relation to mathematics teaching and the effective use of ICT. In England there is considerable change taking place in the teaching of mathematics in the primary age range. At the same time the government is funding from the UK National Lottery, training for all serving teachers to develop their skills in ICT in their teaching. This paper discusses some of the observations of mathematics teaching from the project, some of the work of the project team concerning teachers' thinking about ICT and some relationships with their practices as well as presenting two of the development projects as brief case studies. We then draw out what we see as some of the overall implications for effective development work in mathematics and ICT.

The research project

As part of its remit to improve the quality of teaching in England, the ITA commissioned the University of Newcastle to undertake research into effective classroom pedagogy using Information and Communications Technology (ICT) in primary schools. The ITA intended that this research should:

- test and develop a generic framework highlighting the potential benefits and pitfalls of using ICT in classrooms, particularly in the areas of numeracy and literacy;
- help teachers raise pupil achievements in these areas through supporting
- informed choice by the teachers about the use of ICT in the classroom;
- refine and illustrate specific aspects of ICT use through "rich pictures" ~ detailed classroom case studies of effective teacher practice and development.

The research was carried out in three main stages. During the first stage, a range of schools was identified and the extent of ICT provision determined. Some of the schools were identified using value added (VA) data from the Performance Indicators in Primary Schools Project (PIPS) based at Durham University, initially through a brief postcard survey (2053 schools: 66% return rate). The postcard survey yielded data for 740 classes for which 1996-7 value-added scores were available. Then, to ensure the aims of investigating effective pedagogy were met, only those teachers who were identified as having high or average VA were selected. This enabled correlational links to be examined between a more detailed follow up questionnaire and the VA performance data to identify any factors that were distinguishing characteristics of the high VA teachers. At this stage, 250 questionnaire returns were received (a response rate of 34%).

In the second stage of the project specific teachers from these schools and other 'ICT-rich' schools were investigated to identify pedagogical factors which correlated with increased pupil attainment. Structured observations of four lessons in each of 32 classrooms were compared with data on pupils' performance. In the final stage of the project, data from the questionnaire, the observations and existing research information were used to plan specific development projects in numeracy and literacy with 20 teachers in their own classrooms. Evidence for the effectiveness or otherwise of this development was focused upon pupil attainment using standardised tests. In addition further observations and interviews with teachers were completed. Then a construct elicitation exercise was undertaken with teachers to investigate their thinking and beliefs about teaching and learning.

Some Associations between questionnaire DATA, the observations DATA and pupils' attainment

Analyses of the initial postcard survey data were carried out to see if high computer use across a school year group was linked with high levels of achievement, high V A scores or very positive attitudes amongst the pupils. Generally there was little evidence for this. There was almost no association between the reported amount of computer use and either achievement level or attitude. However there was a relationship with V A in that the small number of year groups where pupils were said to use computers "more than once a day" had positive V A scores on average. Also, year groups where pupils used computers "less than once a month" had negative V A scores on average. This suggested that at the extremes, highly effective teachers tended to have pupils using computers a lot and less effective teachers have pupils using them rather infrequently. The effect size differences between the high and low groups were 0.6 for mathematics and 0.4 for reading, with the most significant result applying to mathematics V A in Reception classes (4-5 year olds). This clearly implies that Reception teachers who are particularly effective in mathematics tend to use computers more often in the classroom. This finding was validated to some extent by a connection between pupil VA scores in mathematics for Reception teachers taking part in the development work who also reported greater use of computers for number work (a correlation of 0.53, but non-significant, due in part at least to the small number of Reception teachers (8) involved in development work).

Some significant relationships between the first set of lesson observations (on four lessons with each of 32 teachers) conducted by the project team and the VA scores of the pupils were also found.

Teacher behaviours

(Please note: * indicates significance at the 0.05 level and ** at the 0.01 level)

- Highly effective teachers tended to use more examples and counter examples (0.61 **) in numeracy lessons, particularly in the plenary phase of the lesson (0.41 *). For example a teacher might give an example of an incorrect solution as well as a correct solution and
- explain why one was correct and the other incorrect. (*This was a particularly strong relationship and suggests that effective teachers use examples as part of their teaching but also exemplify what they are teaching with counter examples for clarification.*)
- Highly effective teachers of Reception classes tended to provide different ICT activities for pupils with special educational needs (SEN) from those for the rest of the class ~ a correlation of 0.75* with VA scores for the eight teachers who reported providing such activities. The opposite trend appears for teachers of older pupils (classes of 6-7 year olds and 8-9 year olds), though the correlation was not statistically significant.

Pupil behaviours

- Pupils tended to model work as examples to their group or the rest of the class in the highly effective teachers' classes - a correlation of 0.51 ** with VA scores for the 32 teachers observed.
- Pupils tended to provide examples more in the highly effective teachers' classes ~ a correlation of 0.45*: these last two findings are clearly linked, though some caution in interpreting this result is called for. The frequency of pupil led examples in the final plenary phase of the lesson does not seem to be so clearly beneficial. Such pupil behaviours in the final phase of the lesson were negatively associated with value-added scores - a correlation of -0.42 (ns) was found for the 18 teachers for whom data was available.

We interpret these findings as indicating that effective teachers make good use of clear explanations, perhaps an unsurprising result and one which reinforces the work of other researchers (e.g. Dunkin and Biddle's (1974) longstanding review of classroom research from the 1960s and early '70s or Rosenshine's work (1983).

Identifying and overcoming barriers to using ICT to enhance teaching and learning in classrooms

Part of the challenge set by the IT A was to work on:

- summarise existing research on identifying and overcoming barriers to using ICT effectively in the classroom;
- exemplifying some of these barriers and the way the project team tackled them through the development work in schools; and
- finally, to suggest ways of understanding these barriers as a means to overcoming them.

The task was approached in several different ways. Many different barriers were identified and these fell into various

categories. Time related issues were consistently identified as the biggest group. The next set appeared to be equipment related and this was followed by pupil related ones. In this latter case, it was possible to make a clear distinction between issues relating to people and those relating to equipment: the number of pupils in my class, the amount of adult support; and the number of machines available for the pupils to use. Perhaps the most important pedagogical issue identified was knowing which software was appropriate in a given situation. However, in general, the pedagogical barriers which teachers identified were seen by them as relatively less important than the other barriers indicated above. These findings match closely the 'problems and challenges' recently reported in by teachers in Scotland (Williams, Wilson et al. 1999).

Later, in a group discussion with some of the teachers, several significant issues were again raised:

- it is difficult for teachers to devote time to pupils who are working on computers, especially where this is only two or three pupils at a time;
- the number of computers per classroom is still low (usually one, occasionally two);
- the time needed for teachers to learn new software appears to be increasing with the complexity and sophistication of the software;
- the time for some to learn how to use basic software for wordprocessing or data handling well; and
- the lack of immediately available technical support; past frustrations, especially with printers, leading to de-motivation; and the ever growing cost of consumables.

A different sub-set of teachers from the original questionnaire was also surveyed (120 teachers, 53% return) and asked to self-rate how confident they felt about tackling particular tasks using ICT. Their responses (n=64) suggest that confidence in using ICT is still a challenging issue for primary teachers. Only *using a spell checker* was an area where the average score indicated that teachers were confident to tackle the task.

The team also tried to explore positive examples of overcoming barriers and several factors were identified as being related to this:

- supporting the development of pupils' skills to enable a clear focus on objectives in numeracy or literacy; providing information about software, but again with specific subject-related objectives in mind;
- finding ways to increase access for pupils; and
- providing copies of software for teachers to use at home. In subsequent interviews, teachers reported that offering the teachers access to technical support and supporting their personal skills had a positive impact on their attitudes and confidence.

Further study of the data revealed that teachers with high V A scores: (a)

tended to report that computers made them feel good about their teaching; (b) thought that computers did not require too much technical knowledge; and (c) said that computer software was not too complicated for children. Since these data were strongly associated with highly effective teachers, it suggests to us that the such teachers see the potential of the technology and try to use it effectively by integrating it as part of their repertoire of teaching strategies and approaches. In the same way the team feel that the barriers are seen by some teachers as something which is to be overcome and by others as more of a barricade which prevents them realising the potential of ICT. To use David Leat's (1999) metaphor, for these teachers it is a case of rolling the stone *uphill*. For the former grouping, those who may have needed help at first, it is more a case of rolling a *stonedownhill*. Once barriers have been overcome the development work gains momentum and overcoming barriers becomes less of an issue as the teacher's skills and confidence increase. On the other hand, for a few teachers in the project, once one barrier is addressed and overcome, another appears. Rolling the stone uphill in this case becomes more like the task of Sisyphus, as once your back is turned the stone seems to return to the bottom of the hill.

To summarise this section, teachers identified ICT-specific barriers as a major difficulty in their attempts to become more effective in using ICT in the classroom. They did not identify subject-specific factors in numeracy or literacy or general pedagogical issues. In some cases these ICT-specific barriers were overcome relatively quickly and easily. In others, these barriers were not overcome easily and required a determined effort on the part of the development team and the teachers involved. All of the information discussed above was used by the team as background to planning specific interventions with 20 teachers in numeracy and literacy, two of which are now described in more detail.

Case Study 1: Developing counting skills with reception pupils using ICT

This case study focused on developing counting skills with 4-5 year old pupils. The pupils created counting pictures

using a children's drawing and painting program². The activities were designed to complement other numeracy activities and to act as a focus for discussion between the researcher and the teacher. The development work took place over two terms with two different classes of pupils. The results from the standardised testing³ suggest that the teacher was able to use ICT effectively as part of her teaching to support the development of her pupils' counting skills. Using detailed knowledge of how young children learn to count and the errors that they commonly make was an important feature of the development work in leT and mathematics.

The teacher has been at the school for six years and usually teaches the Reception Year. When planning activities she likes to make links between different activities and to draw out connections for the children. " *they might need work on number recognition, or using number lines, and it isn't always linked. But usually we do something that is to do with counting, a counting rhyme or acting out a song which is linked to other activities.* " This approach is consistent with the new National Numeracy Strategy (Department for Education and Employment, 1999) recommendations for the Reception year currently being introduced in England and with recent research on effective teachers of mathematics (Askew, Brown et al, 1996). At the beginning of the Summer term, some pupils were making errors in reciting the number names accurately (particularly numbers from 13-19 and at the decade transitions such as 29 to 30), some had inaccurate one-to-one touch counting skills and strategies which led them to give an incorrect total at the end of a count, and some were also unable to identify the correct numeral(s) to go with a number name with numbers up to 20. These matched previous findings of other researchers. The teacher was therefore keen to address these issues in a broader way. She saw ICT as enabling her to do this more effectively than she had been able to do with previously available software which focused only on numeral recognition. "*(It) was quite different from anything (that) I've used before, (which) had been very closed.* "

The teacher found the diagnostic information from the baseline test very useful. It gave her detailed information about the particular counting errors that specific pupils were making. In addition to the work using ICT she planned other numeracy activities to address pupils' particular difficulties. The teacher wanted pupils to be able to practise specific aspects of counting and therefore emphasised different counting skills with different children. The software has the facility to let children stamp a variety of pictures onto the screen thus allowing them to work on the different aspects of counting which had been identified in the initial assessment.

The teacher thought that having pupils create mathematical pictures, and count out loud as they did so, enabled them to use the ICT more independently. They were able to create a variety of pictures over a period of several weeks. This matched a number of the teacher's mathematical objectives for the term such as using their counting vocabulary, improving the reliability of their counting, teaching them more systematic counting strategies and helping them to recognise and use numerals. "*We didn't have much in the way of numeracy materials, using the (JeT) has really helped, and the children have used a lot more mathematical language.* "

A target group of five pupils was identified whom the teacher thought would benefit from the ICT work, together with a control group of 3 others. A standardised test was used as pre and post intervention. By the end, the target pupils all showed that their counting and number ability had improved in particular. They had also improved relative to the other three pupils (an average of 8-point gain in age-standardised score compared with an average gain of 1 for the control group). This development work was repeated in the autumn term with the teacher's next class, but without a control group. The class made impressive gains. Their age-standardised score improved by an average of 15 points (1 SD) in just over two months.

It is clearly not possible to claim that the pupil score improvements were directly due on either occasion to the ICT activities, especially as the teacher used the information from the standardised test to inform her planning more broadly. However the results do suggest that carefully planned and structured ICT activities with clear mathematical objectives can play an effective role in improving pupils' counting skills.

Case Study 2: Developing understanding of decimals with Y4 pupils (8-9 years) using portable ICT equipment

In this case study, the teacher wanted to introduce her class to decimal notation. The school's mathematics policy, like many others, follows very closely the National Curriculum and so she felt she was almost directed to teach this through the medium of money notation. However, in the UK there is a culturally related problem which makes this quite complex. £3.24 is not seen as a single number of pounds but rather as two closely related numbers: three pounds and, separately, twenty-four pennies. This leads to the common error of writing the amount as £3.24p. It is almost as if we have an Imperial notation imposed on a metric system. The result is that for teachers of 8-9 year olds, this becomes an unnecessarily difficult hurdle when teaching decimal number, so one of the teacher's main concerns was the issue of how meaningful the pupils would find such decimal numbers. Given that she eventually wanted her pupils to be able to order and even calculate with decimal numbers, she felt that it was important to use numbers where the pupils could draw some understanding from the context.

After discussing matters with the Project Team member, she agreed to try using *time* as the medium rather than money - time measured through the use of ICT. The activity used an e-Mate (a robust portable computer designed for children) connected to a pressure-mat sensor. This allowed the children to generate times in seconds to two places of decimals. The equipment enabled two different types of activities to be timed, each of which needed different interpretations as to which was the 'best'. The first activity required the children to stand on the pressure mat and jump in the air before landing on the mat again. The times for these standing jumps were typically 0.43 or 0.37 seconds. Here, the 'best' time was the biggest number - the longest time in the air. The second activity exploited the portability of the equipment as the children used the ICT equipment as a timing gate. They took it out into the playground and ran from one side to the other and back again. As they set off, they trod on the mat starting the timer. It stopped when they returned and trod on it again. Here the 'best' time was the smallest number - the shortest time taken.

The teacher chose to use the ICT equipment for two reasons. The first was to generate 'real' numbers which the children could understand from the context in which they were produced. The second was as a stimulus to get the children thinking about what 'best' meant and about using decimals in a specific context to achieve this. She also wanted to use aspects of the published scheme which the school uses as part of its approach to mathematics throughout the school but also to make links to understanding decimals in another way through the ICT activity. Using the ICT also had an effect upon the choices related to her expectations of the children. She had not done a lot of work on decimals with previous Y 4 classes. This, she thought, might have been related to her own needs as well as those of the children.

"I found decimal fractions quite difficult for a lot of children. It may be the fact that I didn't expect them to take it much further that was part of my problem as well. The e-Mate stimulated their interest to learn and understand beyond my expectations. I would never in my wildest dreams have thought they would cope with this. "

Not only was there a global shift in her expectations of what the whole class could achieve, but there were also a few significantly different changes for individuals.

The pupils completed a standardised mathematics test before and after the intervention. The results indicate that the mean number-age rose from 8 years and 4 months to 9 years and 5 months in just four months, a gain that is statistically significant at <.001 level. The test did not specifically look at using decimals, although it was a component of the test. Whilst it is important not to attribute this gain solely to the ICT activities, it is thought reasonable to suggest that it will have played a part in developing specific mathematical skills and understanding. In addition, it also seems reasonable to assume that it will also have played a part in the more general increase in the pupils' confidence and attitude. The idea that working on developing one area of mathematics has a non-planned but significantly beneficial effect upon others is consistent with the work of Denvir & Brown (1986) and is therefore not surprising.

Some conclusions and implications

Obviously we have to be somewhat cautious about over stating any claim based solely upon this work, but there are some interesting outcomes. It appears that effective teachers use examples and counter examples as part of their normal teaching. The pupils of such teachers tend give examples during lessons and to model their work both when talking to the teacher and to their peers.

The *teachers' and the pupils' levels of personal confidence appear to have conspicuous effects upon the outcomes when measured through pupil achievement*. What is more, the degree of their confidence in using ICT appears to be rooted quite firmly in their personal skill levels. Our data would support the view that, on the whole, effective teachers who use ICT are teachers who are confident with ICT and that they are much more comfortable with ICT as an enabling addition to the pedagogical armoury. Where ICT is not adopted as a normal part of their teaching, certain barriers play important parts in whether and how teachers in primary schools adopt ICT in their teaching. In trying to explore this, the research team found that if the specific ICT-related issues were addressed head-on, this would not necessarily lead to future success for the teacher. What we feel was important was to try to work around the problem rather than to confront it. This was done by helping the teachers to keep a very clear focus upon desired mathematical content targets for the lesson(s) and not to get sidetracked into the ICT issues. Principally, this was achieved by having someone in their classroom helping to get their pupils over an initial threshold of personal ICT skills which allowed the teachers to concentrate upon the mathematical purpose of the lesson. Using this approach, it was as if the original hurdles were by-passed rather than confronted. The result was that the importance of solving ICT issues diminished considerably. Once past this hurdle, it was as if the changes became self-fuelling and the teachers began to use the ICT to achieve improvements in their teaching without further help. ICT was seen as insufficient in itself to stimulate changes in their pedagogy. However given assistance to give their pupils sufficient skills so that they could then concentrate upon the mathematical task in hand (rather than the technicalities of using the equipment), they could achieve some surprising results - surprising often to themselves as well as to outside observers. We believe this

may well have implications for a UK government, which seems to believe that the large scale and very expensive adoption of ICT could be an important factor in solving a pressing teacher shortage.

The data and case studies presented here are only a small selection of the initial findings from a substantial, very data-rich project and do not attempt to be a complete report of all that has been measured and analysed. They are seen as being principally illustrative and not conclusive. Possibly the most important thing to say is that whilst many of results reported are correlational, the team are crucially aware that there should be no attempt to suggest that there is necessarily any causal link implied or intended, only that the findings may well indicate areas where more detailed and carefully structured investigation may be necessary to establish firmer links. However, we believe there are some very interesting and possibly important findings that may well prove to be significantly influential in the future.

We conclude with two points:

- first, we cannot see machines replacing the essential element of the personal relationship that exists between teacher and pupil in the primary years of schooling, though the addition of new technologies may enhance this teaching and learning relationship; and
- second, we would not want to underestimate the effect of the personal relationship, which develops between teachers and those supporting their professional development as an important factor in successful development.

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An ICT rich mathematical education environment: the secondary mathematics PGCE

Dave Miller Keele University

This paper provides information about how one institution has decided to provide an information and communications technology rich mathematical education environment as part of the PGCE course. It provides a rationale for the course design, and gives details of a number of key features of the course.

Background information

The use of ICT in subject teaching at the secondary level is not just an issue for mathematics teachers, but an issue for teachers of all subjects. At the initial teacher education (ITE) stage there will be a variety of views on how the information and communications technology (ICT) skills of student teachers should be encouraged and developed. We all have our own beliefs that underpin the way in which we design and teach a mathematics PGCE course.

Until the introduction publication of circular 10/97 (DfEE, 1997) and the subsequent publication of circular 4/98 (DfEE, 1998) mathematics ITE courses will have attached different levels of importance to the use of information technology (IT) in mathematics. Circular 4/98 and its requirement that all those gaining Qualified Teacher Status (QTS) must achieve the ICT associated standards meant that all courses need to provide a minimum level of provision to ensure that this would happen.

We decided that we wanted to embrace an ICT rich mathematical educational environment as far as we could, in order that we might best prepare our students not only to pass the ICT standards but also to become 'ICT rich' teachers. In order that we might do this, we looked at factors that might help and hinder us. We wanted to design the correct environment given the constraints on time, finance and current levels of resource.

In our view the major influencing factors that affect the use of ICT by students are:

- course design features (institutional and subject)
- institution staff and mentors and their beliefs, attitudes, pedagogical practice and experience
- students and their beliefs, attitudes and pedagogical experience
- access to equipment by students (at home, in the institution and in school)
- the opportunity to practise and use ICT with pupils
- the support available from the staff for the students

To provide the correct environment meant that all factors needed to be worked on, however some might be more easily changed than others. The easiest for us to work on immediately were: the course design; access to equipment in the institution and to some extent elsewhere; institutional support and, to a limited extent, the opportunity to practise and use ICT with pupils. Some of our strategies and ideas related to these aspects are outlined below. In our view, other factors, including those involving beliefs and attitudes are much harder to work on, but these factors may be influenced by work undertaken on the 'easier' factors.

The leT culture

At the course design level, across all subjects, it was decided that ICT would be 'highlighted' from as early as possible in the recruitment cycle. For the mathematics staff, this approach was considered essential to help develop the ICT rich environment, while staff in another subject also considered this approach to be essential (typically as a means to help candidates realise that they had to have high ICT skills in order to pass the course).

In practice this meant that at the introduction to the department all candidates are told about the importance of developing ICT skills before starting the course and they are advised that it is an advantage to have easy access to a reasonably up-to-date PC. For the mathematicians this is followed up at the interview, where specific questions are asked about ICT skills, both personal and in relation to use in mathematics, and candidates are advised about the importance of improving ICT skills before the start of the course. Standard course letters remind all successful applicants about the importance of gaining, or improving, ICT skills before the course starts and an ICT audit document is sent out to all, to be returned well in advance of the course start. In this way

all tutors have an audit of the ICT skills of their subject group on the first day of the course.

The course design further attempts to set an ICT culture for all courses by providing:

- a minimum course-wide entitlement for all students
- regular timetabled subject-based ICT experiences for all students - one in every complete institution-based week
- a minimum expectation that all students will have used ICT at least twice with a class or small group of pupils on the 7 week (initial) teaching practice
- a subject based ICT assignment that has to be completed by all students after the 7 week teaching practice
- a form to monitor the use of ICT by the student with pupils
- notebook computers for students to use in schools with pupils*

*still being implemented (notebooks are currently available for certain subjects only, including mathematics)

The teaching of ICT in mathematics

The impact of student perceptions of 'subject' culture is discussed by McMahon and Gardner (1995) who draw attention to the powerful influence exerted by the attitudes and practices of lecturers and other professionals. Students are quick to adopt the current climate of opinion about the role of new technologies that they see exemplified by their own subject teachers.

The use of the subject tutor as a role model, with all ICT work in a subject context provides: an opportunity to create a purposeful and realistic context for ICT learning; a means of using subject pedagogy as the framework for ICT skills development; the facility to build on existing subject knowledge; and the environment to give prominence to pedagogical knowledge as the basis for the effective development of ICT to support teaching and learning.

The importance of locating the development and acquisition of ICT skills, knowledge and understanding in a setting which the learner identifies as purposeful and realistic is well documented and considered as a cornerstone of good practice. A range of studies (for example, Oliver, 1994) have explored this issue and all draw attention to the need to translate this principle into the everyday practice of teacher trainers.

Hence it was decided to provide only subject-based ICT sessions for all, at pre-determined times regularly throughout the course, with the 'tuition' provided by a subject specialist. Most students, including those in mathematics, have one of their subject tutors taking the ICT sessions.

In all other sessions where ICT is used, the normal mathematics teaching room is used (which is usually computer free) or a swap is arranged to make use of one of the computer network rooms. This 'simulates' the school environment, though the pressures and the equipment available are slightly different (though even now we have one partnership school where our mathematics students can use a projector linked to a notebook).

Notebook computers

The early work of Gardner et al (1992), amongst others, suggested that when teachers are given access to notebook computers, they will use them to improve their own personal skills. So, in 1993 the mathematics education section bought 4 notebook computers for use exclusively by the 15-25 mathematics PGCE students on the course. These computers could be booked individually or as a 'set' by any student for personal use or use within school. By 1997, the speed of software and hardware development was such that it was necessary to replace the machines with 4 others. The successful use of these is such that there is now an institution policy of a rolling programme of notebook purchase for use by PGCE students.

Assessment

It has also been PGCE policy for a number of years now to link certain aspects of ICT knowledge, understanding and skills with the formal assessment process, in the belief that this would ensure that all PGCE students learnt certain minimal, basic ICT skills. All course assignments have to be word-processed, spell-checked and provide a word count. All PGCE students have to submit an ICT subject-based assignment in January. The nature of the assignment is determined on a subject by subject basis.

Key features of the ICT in mathematics course *Basic Support/or Cooperative Work*

BSCW (Basic Support for Cooperative Work) is a free access website (<http://bscw.gmd.del>) where any individual can register and then create their 'own' area. Once an individual has created an area other people who have registered at the site can then be invited to join that area. Although there are limitations on how this site can be used, it is free and easily available to anyone with an email address and Internet access.

In advance of the first ICT based mathematics session, an area for the PGCE mathematics group is created and a number of files are left there, including: a lesson plan proforma; the institutional email addresses of all members of the group; a short list of key websites of interest to mathematics teachers; a copy of the 'body mathematics' lesson plan used at a session earlier in the week and the spreadsheet file associated with the 'body mathematics' data collected from the group.

In the first ICT session all group members join the site, a process that involves selecting a username and providing an email address. Members of the mathematics group are then invited to join the PGCE mathematics area (this year about 50% of the students provided their own email address rather than the institution provided address).

It is the intention that the BSCW site should be used regularly throughout the course. To 'initiate and encourage' such use, students have to place a number of files onto the site in order to pass the ICT based assignment. These files include spreadsheet files and lesson plans. At other times requests are made for students to place files here: examples include lessons plans that went well, questions asked at job interviews, ICT lessons that have worked and topic plans. The site has also been used to place files requested by students, for example a WORD file for centimetre squared paper, and to provide a direct link to partnership school websites that may be of interest to members of the mathematics group. It is also possible to use the site to send email to group members.

Given that the site is not connected to the HEI, it is possible that all group members can still use it after the course is finished, though those group members with an institution email address will lose the opportunity unless they provide an alternative address. This could prove to be an interesting forum once the course has finished.

Spreadsheet skills

The ICT audit at the beginning of the course usually finds that virtually all the mathematics students already have standard, personal spreadsheet skills. In addition, many of the standard uses of a spreadsheet are covered as they arise in topics in the general mathematics sessions. Examples of these are: Ibodyl mathematics session for 'average' functions and scatter graphs; the difference method when we illustrate use of formulae and copy

against diameter; and the use of number grids leads into the spreadsheet as a number grid generator. As a consequence the ICT based spreadsheet sessions focus on optimisation problems and interactive worksheets.

Optimisation problems

In the first ICT session students are shown the Sheep pen problem (ITA, 1999) and are asked to consider how they would use a spreadsheet to help find a solution. Following a brief discussion, they solve the problem. This provides a useful entry to such problems and links directly to the TTA ICT documentation. Later, most of the students become more familiar with such problems as part of coursework activities for pupils, though often mathematics teachers in schools do not consider the use of a spreadsheet to be essential (or even desirable).

As part of the ICT mathematics assignment, students have to find or invent a suitable optimisation problem, and produce a prototype solution by spreadsheet. The solution method has to be as simple as possible to understand (aiming for something a beginning pupil could construct for themselves, not necessarily the briefest or most condensed approach). This gives the students an opportunity to do some mathematics for themselves and, in most cases, to solve an unusual problem (for them). Surprisingly, many students do not at this stage check their answer using calculus or link it to the geometry or practicalities of the situation. It is quite common for students to produce the results without reference to a graph.

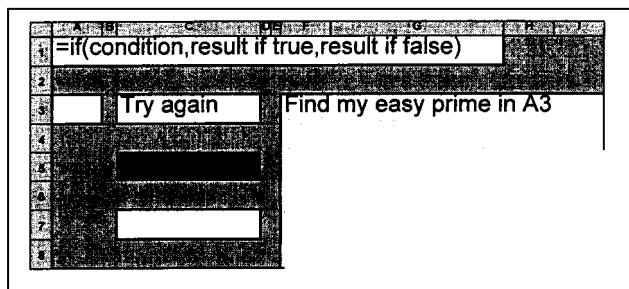
Once marked, later sessions on pedagogy and ICT skills consider the use of calculus to help solve optimisation problems; optimisation problems as an introduction to calculus; the use of appropriate graphs and how a spreadsheet can provide a quick display of numerical information; and efficient spreadsheet methods for students, teachers and pupils.

Additionally, as part of the assignment, the problem has to be incorporated into a lesson plan (it is hoped that it will be taught later) and both the lesson plan and spreadsheet have to be placed on the BSCW site.

Interactive worksheets

In another early session students are introduced to interactive worksheets in Excel, see for example Eagle, (1996). These worksheets are Excel files that provide pupils with an activity and then provide feedback for the pupil.

Students are shown the simple interactive file given below. It illustrates the 'first principles' of an interactive spreadsheet: a problem to be solved; a colourful display; the use of an 'IF' function and the use of black type in a black shaded cell (C5) to hide information.



When the number 5 is typed into cell A3, 'Well done' appears in cell C3. Cell C5 is 'made visible' by 'shading' the cell any colour except black (or changing the font colour) - since it starts with black text in a black shaded cell. Once cell C5 is 'made visible' it is shown to contain a 'nested' IF function so that 'Try again' or 'Well done' will not appear in the cell until something has been typed into cell A3.

In the early stages students' worksheets usually consist of routine 'drill and practice' type experiences for pupils - offering feedback based on the pupil's answers. Files are always colourful and usually provide students with a feeling of achievement when they work properly (and all students achieve success reasonably quickly in the first ICT session).

As part of their ICT assignment students are required to design and then use an interactive worksheet on a notebook computer with at least 2 groups (or pairs) of pupils. They also have to produce a report based on this use of the worksheet with pupils and place the worksheet on the BSCW site.

Typical early examples of files are 'single use' files that fail to use the power of the spreadsheet. For example, in the table below, a student will use the IF function to look for the answer 20, rather than the answer (AI x CI). So typically FI would contain '=if(EI=20,"Well done", "Try again")' rather than the more efficient '=if(E I =AI *C I , "Well done", "Try again")'.

	A	B	C	D	E
1	5	x	4	=	

Others, not realising that there is a ROUND function, check for the required solution of 5.7 (5.7274 to 1 decimal place), rather than using the 'ROUND' function in the form ROUND(BI,I). So typically FI would contain '=if(EI=5.7,"Well done", "Try again")' rather than the more efficient '=if(EI=ROUND(BI,I),"Well done", "Try again")'.

	A	B	C	D	E
1	Round	5.7274	to 1 decimal place	=	

These interactive files therefore develop a 'need' for a wider variety and more complex spreadsheet functions than would otherwise be needed by an individual. In virtually all cases students will at some point want to do something different that they do not know how to do, so they use each other, or one of the spreadsheet experts in the mathematics group or the tutor to acquire the necessary knowledge. At times no one has the knowledge, but to date, a solution has always been found. Those students with the highest level of spreadsheet skills are challenged by the tutor to use macro linked buttons, hyperlinks and scroll bars. The focus of learning is not 'what does this spreadsheet instruction do?' but instead 'I want to do this on my spreadsheet, how can I do it?'

The development process forms only a small part of the work, which is also concerned with pupil motivation, children's learning and understanding of mathematics. All students are given the opportunity to use a worksheet with pupils. In some cases, following student-mentor discussion, the student prepares a special worksheet on a particular topic (one just taught, or revision of a few weeks back) at other times the student chooses a topic and uses it 'cold'.

Sometimes the use of the worksheet is integrated into the scheme of work, at other times pupils volunteer to use the spreadsheet at lunchtime.

In almost all cases students report that the worksheets, when used on the notebooks, are popular with pupils ('pupils wanted to stay beyond the lesson and asked to use them again') even though the topics and the mathematics seem somewhat basic and ordinary. Pupils like the use of praise ("Brilliant - you are correct", "Well done") and colour, and the immediate feedback that comes from the worksheet ('It's better than using a book, when you might get five wrong before the teacher tells you').

Some students also report that pupils want to try and understand how to answer the questions, rather than just get the answers right - hence there is potentially more scope for using such worksheets to introduce new concepts, rather than just providing practice. However, this may be different if the students were not directly observing the pupils using the worksheet.

In many cases students have also commented that pupils are impressed that the worksheet is the work of the student, and in a number of cases the pupils have wanted to know how to make such a worksheet themselves. This is an area where there may be scope for pupils to create files for other, possibly younger, pupils with the aim of improving the mathematical understanding of the younger pupil (and we would expect of the worksheet 'writer') - though this is not just a spreadsheet or software related activity.

Some students, possibly those with a 'different awareness', design more open ended worksheets; for example, make all the answers 100 (pupils are given blank spaces and an operation). Another example is where a correct answer provides a co-ordinate, which is used in a pencil and paper coordinate activity.

In all cases, students write about improvements that have been, or could be made to the worksheet. Common examples are not protecting the formulae in cells, so pupils inadvertently 'destroy' the worksheet; the use of random numbers to generate new problems; linking solutions to numbers in the cells; and the time taken to remove all the answers and start again. The solutions to these are provided as feedback on the assignment. All students are also given solutions to common problems and advice and suggestions for further development.

Invariably, the issue of pupils' learning arises in some of the reports, and it is also often found in the similar reports that students have to write based on use of the Smile for Windows programs with pupils. These issues are considered at a later session, when students will have had more classroom experience in using ICT with pupils.

Conclusion

So far, we are in our first year of use of the BSCW site and are awaiting developments to see how students will use it once on the main teaching practice - though the use of it by IT students last year was encouraging.

The optimisation and interactive worksheets have been used for the last three years and we have been pleased with the way in which these two spreadsheet activities seem to achieve many of our aims by: helping enhance the students' subject knowledge; providing an initial, highly positive mathematics ICT experience with pupils; giving an insight into pupil's learning; developing the spreadsheet skills of students; showing that mathematics can be presented in ways that motivate pupils; and providing some of the practical 'backbone' on which to build the pedagogical 'body' of knowledge.

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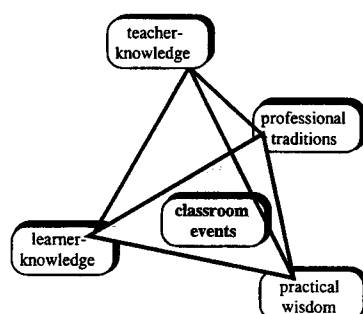
Short Activities with Spreadsheets: Mathematics, leT and Mathematics Education

Pat Perks and Stephanie Prestage University of Birmingham

This paper offers a description of the issues which arise from working with pre-service teachers on mathematics using spreadsheet files in whole class activities. These activities are deliberately used in short time slots and serve many purposes. They model tasks which could be used in the mathematics classroom; they support the development of students' subject knowledge of mathematics; they support the development of students' subject knowledge of leT; whilst offering a focus for discussion and reflection to enable professional development for mathematics teaching.

Introduction

Contact with PGCE students over the years seems to get shorter and shorter whilst the criteria against which they are matched for goodness of fit seems to expand (does it only seem exponentially?). This in turn implies that each session has to work on many levels, so that the many themes for teacher development can be revisited as often as possible and in different mathematical contexts. Elsewhere we have described the complexity of becoming a teacher (Prestage & Perks, 1999) summarised in figure 1.



[figure 1: a model for subject-knowledge]

If we take just one aspect, mathematics subject knowledge, then we believe that students must attend to this in various ways even though they have more than sufficient learner-knowledge for an official audit. Our long-term aim is to help the students synthesise, via evaluation and reflection (Schon, 1987, Tripp, 1994), different knowledges gained from different experiences through the year to develop what we have called teacher-knowledge in mathematics subject matter. In fact work with pre-service teachers needs to reflect many facets, mathematics subject knowledge, ways of working in classrooms, developing adaptability to enable students to develop their teaching skills.

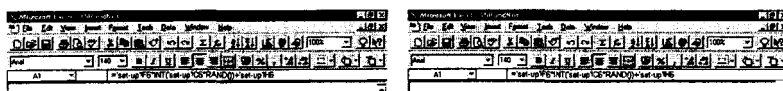
Our own practical wisdom includes the knowledge that students cannot easily extend ideas presented in a particular session to the generality of the situation (c.f. Mason & Pimm 1984), either in terms of adapting the mathematics to other situations or extracting issues for teacher education. Sessions with students, therefore, have to be multi-layered, reflecting a spiral curriculum that remains a challenge to achieve as time for 'mulling' is reduced.

The place of leT in method sessions

Student teachers are required to hold a certain amount of learnerknowledge about ICT (how to use the software themselves) as well as its appropriate use as a resource for learning mathematics (practical wisdom*). Opportunities for the students to use ICT in schools are infrequent so the use of ICT underpins our course and we take many opportunities to use it with the students. Crisan (1999) reminds us that the research on ICT has failed to regard the teacher as learner in its focus on pupil learning. We plan therefore over time to balance the students' learning of ICT with their learning about the teaching and learning of mathematics. To this end a regular feature of method sessions are a set of spreadsheet files with a TV attached to the computer. We use this particular technology in short sessions (15 minutes) on several occasions rather than fewer longer sessions in the computer room which helps to move the focus of learning over a time period from learning about the technology itself (how to use spreadsheets like this, how to write the program) to the learning of mathematics with leT. The technology then becomes another resource for considering mathematics and mathematics education.

[*Practical wisdom is, in our terms, an integrated version of Shulman's pedagogical content knowledge (Shulman 1986). Pedagogical content knowledge includes having activities for the classroom. Practical wisdom encompasses the idea that teachers use activities effectively in different classrooms, know how to change them to meet different learners' needs and how to exploit them to extend their knowledge of connections in mathematics]

One example [Other examples can be read in Perks & Prestage 1999; 2000.] of a spreadsheet in the files offers, simply, a large display of a number (figure 2) generated randomly using the random number function guided by parameters chosen by the user.



11 5.75



figure 2: possible screen displays

This particular file can provoke a lot of mathematics. In a session we might use the numbers to chant tables, multiply by powers of ten, as a stimulus to form angles from arms, geostrips or card circles or to conjecture about the set of numbers being used or even for ideas of statistical 'proof'. We recognise that in demonstrating activities, which exemplify our own practical wisdom, we are offering these to the students in the form of new professional traditions which need to be reflected upon if they are to be integrated into the students' practice.

Modelling a variety of activities allows different learner-knowledge and professional traditions to be considered, as shown in the table below.

Activity	mathematics learner-knowledge	professional traditions
chanting in response to a number - 2 more, 5 less, 3 times, half of etc. making an angle	mental arithmetic, number bonds, 4 operations on different number sets estimating angles, acute, obtuse, reflex	use of questions; role of speed for rehearsing number facts use of practical apparatus; focus on turn
random number $\text{INT}(45 * \text{RANDO} + 15)$	language of number notion of proof/data collection, sampling, range	encouraging conjecture an hypothesis making; ways of testing conjectures; alternative approaches to defining/proof

Such activities can lack specific focus on the nature of the teaching activity, the style itself implies that the student needs a computer and large screen in order to do this type of mathematics. Thus the mathematics and the ICT can be rejected together when "I don't have a computer in my classroom" is the cry. The examples are all specific cases and the students are expected to create the generality from these special cases for themselves. If they stay with the particular an example may be deemed inappropriate because "I'm not doing that topic" or "That's too hard for my pupils". The framing of a generality might enable the changing of the topic application or the level of difficulty.

In addition to becoming familiar with the software and doing some mathematics there are opportunities for discussion about issues in mathematics education as listed above or visiting many of the themes threaded throughout our course, for example:

- the place of hooks,
- practice and whole class interaction,
- adapting activities - new activities and new questions,
- the use of ICT affecting the management of the situation.

Each new activity allows ideas to be revisited in differing contexts to permeate the students' thinking, whilst the spreadsheets permit the focus of the computer as a resource.

The place of hooks

The use of a hook is often a feature of our teaching (e.g. Paddington in Prestage & Perks, 1992) and we encourage the students to find ways to attract the pupils to a lesson. Discussions with students focus on the need to capture the attention of and to involve the pupils in the activity. The use of technology itself offers a strong hook. Many of the activities could be done with flashcards or pencil and paper, but the screen appears to have its own fascination as well as allowing the management of the activity to be at the planning level rather than at the execution stage.

The place of practice and whole class interaction

A major feature of the spreadsheet files involves the use of practice. In responding to random numbers from 1 to 10, students can be asked to add 3 each time the number appears. Community chanting is easy. A switch to the three times table is usually met with equal confidence. There is a less confident response to the seven times table and the seventeen times table is met with resistance. The public non-declaration of learner-knowledge remains uncomfortable even with the most mathematically able. The reproduction of actual classroom emotions provides vital discussion points for our students. The challenge does not have to be obviously outside the expected learner-knowledge (who has to learn their 17 times table?).

The random number file was used during the a session this year when integers in the range -10 to 20 were chosen. The students had to respond by chanting a number which was ten times the number on the screen. When the screen showed 3 or 7 the response was quick - thirty, seventy. For the students the activity was easy until the routine was interrupted by the appearance on the screen of -2. This was greeted by a pause, slowly stretching to "negative twenty". The pause illustrates a challenge, as the 17 above, to learner-knowledge as the students rarely work with negative numbers at the same facility level of positive integers.

Because they do the activity the students may relate more strongly to many of the issues related to practice (amongst many of the ideas they have to work on). For example, the activity may be insufficiently challenging for all, this then reflects back to the decision-making of the teacher. There are the skills involved in selecting questions, the original number set and the pace and length of the activity. Some of the students are not necessarily involved, because 'they know', and their experiences can be related to the needs of the individual versus whole class activity.

The students are also aware that in the whole class chanting, some lack of response is hidden, some hid their own responses. However, this lack of response can be judged to be of benefit, in that the non-responding student may be being offered a learning opportunity by listening with the others. This is clearly another aspect where teachers have to balance difficult decisions and our student teachers have to realise that one activity does not different types.

Any activities modelled on the course, when used in classrooms, will meet different pupil needs. Most situations will provide a class with opportunities for some to rehearse, some to improve their facility and for some to take steps towards learning. The challenge for the practical wisdom of our students is how to integrate practice as a regular feature of lessons whilst also creating alternative contexts for the same mathematics and recognising the different needs of learners.

Learning to adapt activities

Good teachers can adapt activities to suit the needs of learners or to extend the exploration of the mathematics. For example, the large random numbers can be used to practise tables but such numbers can be used as a focus for other scenarios. If the numbers are used for responses such as chanting seven times the number which appears on the screen, this extends to other tables and to other number sets not just 1, 2 to 10, but 10, 20 to 100 or 0.1, 0.2, to 0.9 or ... That tables can be extended to seven times subtract one or seven times and double or ... The activities might be changed in terms of resources offered, if for example the numbers are 10 to 360 for estimating angles, the angles could be made with arms, geostrips joined together, interlocking card circles or sketched. Equally importantly the mathematics can be made progressively more difficult in a variety of ways and so the students reconnect their own mathematics and begin to think about progression and sequencing through some mathematics.

These ideas are summarised in a splurge diagram (figure 3) a tool we expect the students to use when analysing a topic prior to teaching and also for working on adaptation and connections.

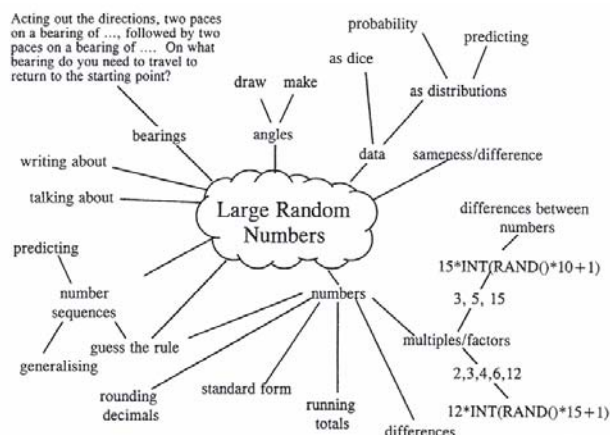


figure 3: a splurge diagram for generating ways of using the random number file

Learning to ask questions

One of the other skills necessary for purposeful use of these spreadsheet files lies initially in the teacher being able to ask closed questions, where the repetition of the questions enables mathematical connections to be rehearsed by learners, and then eventually for the teacher to ask more open questions to allow learners to explore the mathematics.

In a summer term session, when students had finished their main teaching practice, a spreadsheet file which shows up to ten red dots and up to ten blue dots randomly on the same screen was used - a seemingly innocuous screen display. The students were asked to write down and then share in groups the questions they might ask if they were to use this spreadsheet. The initial questions/tasks give evidence of their developing skills:

- How many red counters?
- How many blue counters?
- How many more red counters than blue counters are there?
- Find the difference between the number of blue and red counters.
- Find the product of the number of blue and red counters.

Double the number of blue counters and add the number of red counters.

But then one group who had worked on probability on teaching practice remembered conversations about connecting fractions, decimals, proportion and probability; their questions using the screen display formed a litany for developing ideas related to probability and gave evidence to the emergence of their undoubted practical wisdom and of teacher-knowledge in this area of mathematics:

- How many red counters are there?
- How many blue counters are there?
- What fraction of all the counters are red?
- What fraction of all the counters are blue?
- What proportion of all the counters are red?
- What proportion of all the counters are blue?
- If I were to put these counters in a bag and I drew one out without looking, what is the probability that the counter will be red?
- If I were to put these counters in a bag and I drew one out without looking, what is the probability that the counter will be blue?

or

- How many red counters are there?
- How many blue counters are there?
- What is the ratio of red counters to blue counters?
- What is the ratio of blue counters to red counters?
- If I were to put these counters in a bag and I drew one out without looking, what are the odds that the counter will be red?
- If I were to put these counters in a bag and I drew one out without looking, what are the odds that the counter will be blue?

Rehearsing the first of these sets of questions as the picture changed offered a way of working on the connections in the mathematics and in the language used in probability.

The use of leT changes the management of the situation

In preparing resources for an activity a teacher will consider the purpose of the material to maximise the opportunities for its use. If one is making flashcards, it is useful to be able to use them for more than one type of task - or to have them for a task used frequently - so digit cards become a useful addition to the teacher's kit - two sets allow double figures, addition, difference, products etc. Similarly in making a versatile spreadsheet file it is sensible to be able to change parameters for different situations.

The file for the generator of a large random number is set up to allow the number of numbers to be generated, the gap between the numbers and the starting number. The file can be used to show the single digits in random order, or the multiples of five, whole numbers from 0 to 360, negative numbers or any collection of numbers which can be defined by the three numbers chosen by the user on the set-up sheet.

	C	D	E	F	G	H
5	Number of numbers		Gap between numbers			Starting number
6	15		5			-30

Using the formula `=set-up!F6*INT('set-up!C6*RAND())+'set-up!H6`

the numbers for these parameters will be from the set -30, -25, -20, -15, ... ,40.

By considering how a set of numbers might be generated and used focuses attention upon the purpose of mathematics for the learner in a different way. For example, if the gap is 0.25, pupils may be encouraged to multiply by 4 or double and double (with or without a calculator), the ensuing integer answers can be used to focus attention on the 'quarterness' of the numbers. The management of the ICT situation is easier than creating new flashcards. It is unlikely that one would be prepared to create flashcards for all possible sets of numbers and the task of making might detract from analysing the mathematical purpose of the types of numbers chosen. Also if the session is working well or differently from expected, the use of the spreadsheet allows rapid change of the values to allow focus on a different aspect of the mathematics, which is impossible with flashcards because the nature of the mathematical direction is likely only to occur to the teacher in the moment, as the responses of the learners can be difficult to predict. The opportunity for teacher choice is enhanced because different ideas can be tried quickly. Making the students aware of the potential of the use of technology is a major aim for these sessions. The technology hopefully will become a resource amongst others.

In Conclusion

Within any activity in teacher education there is often conflict between the interests of the students in the subject itself and the needs of teaching, the development of practical wisdom to survive in the classroom and the step beyond that where the learner-knowledge, professional traditions and practical wisdom are synthesised, analysed and integrated to form teacherknowledge of the subject. The sessions using the files offer a strong model for working on mathematics with a whole class and the usefulness of the large screen attached to an always available computer cannot be underestimated. They are also a powerful introduction to many ideas in mathematics education. The students' learner-knowledge is reinforced and the enthusiasm for doing mathematics seems to be rekindled whilst at the same time supporting the beginnings of practical wisdom and the creation of teacher-knowledge about mathematics. Important practical wisdom lies in the place of language, the teacher role in questioning or setting up activities, the role of the learner, for example the non-participation versus the listening of some pupils in the class. Mathematical questions might be prompted by the role of randomness in one activity and order in another.

Whilst recognising that the students' teacher-knowledge may only develop after years of teaching, we need to question whether the elements of our practice which need to be made more explicit to all our students that would offer ways of developing this aspect. The issue may lie in the nature of learning so that it is only in retrospect that these activities may come to form part of the development of the students' own teacher-knowledge, by their use or rejection, the adaptation and the inclusion in the students' reflective development.

Our purposes for the design of these sessions are very clear to us:

- The use of the files in short activities, revisited in different contexts, offers a strong alternative to the session in the computer room. The attention of the students can be more directed towards the mathematics rather than the software itself.
- The repetition of sessions based on the technology is intended to offer the students a variety of examples to help them to extract the generality, to see the application to other situations and mathematics rather than their remaining with the specificity of the particular example.
- The resource (the computer) does not become the focus of the session, this remains with teaching and learning.
- The resource can be balanced by alternatives, (e.g. flashcards) to retain this focus on teaching and learning.

The outstanding issue is whether these purposes are sufficiently explicit and aid our students' professional development.

We recognise the need for varied resources, to integrate the use of ICT into mathematics lessons, but more importantly we want our students to develop a wide knowledge of possible teaching strategies and understand the purpose of such activities for the learning of mathematics so that their teacher choices are as widely developed as possible.

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Assessment as a Means of Implementing Information and Communications Technology in Initial Teacher Education

Declan O'Reilly University of Sheffield

In the UK, the Teacher Training Agency requirements for ICT impose formidable demands on Initial Teacher Education institutions and their school partnerships. Lack of expertise in the use of ICT, lack of resources, and a reluctance to deploy software in mathematics lessons are amongst the barriers to the successful implementation of these requirements. This paper describes how an ICT portfolio was used with a group of PGCE student teacher in an attempt to overcome some of these obstacles and provide a foundation for future ICT use.

Introduction

At the present time in the UK, the bureaucratisation of teacher education is well under way. The body responsible for teacher education, the Teacher Training Agency (ITA), has imposed a whole raft of regulations (DtEE, 1998) on Initial Teacher Education (ITE) institutions. Some of these are general requirements of teaching, the so-called 'Standards'; others are subject specific; whilst one section (op cit., Annex B) sets out the requirements for Information and Communications Technology (ICT). As far as we are aware, there have been no feasibility studies on the practicalities of implementing any of these regulations. Presumably, the IT A feel that as long as they are formulating policies, others can worry about practice.

Listening to colleagues in school and other universities, there seems to be no shortage of such worries, particularly with regards to the ICT requirements, which have been described by one commentator (Davis, 1998, p. 155) as imposing "dramatically increased demands for change in the infusion of information technology (IT) into initial teacher training." This paper arises from that concern. It gives an account of the successes and failures of attempting to implement ICT in Initial Teacher Education by means of a compulsory assessment portfolio.

Discussion

Of the main routes into secondary mathematics teaching, the one year Post Graduate Certificate in Education (PGCE) faces particular problems. Selection procedures can ensure that as far as possible candidates have sufficient subject knowledge to teach the requisite age range. Whether they have ICT skills relating to mathematics is a matter of chance. Mellar and Jackson (1992) observe that, whilst mathematics students were strong relative to students of other curriculum areas, only 28% had used a spreadsheet and only 35% had used a database, both of which feature in the National Curriculum. Subsequent research (Mellar and Jackson, 1994) suggests that this situation is improving, but it seems safe to say that equipping PGCE students to utilise ICT in the teaching of mathematics will remain a problem for ITE institutions for the foreseeable future.

Research indicates that providing students with distinct courses in ICT does not resolve the problem of getting them to deploy those skills in the classroom (Wild, 1995; Easdown, 1994; Somekh et al, 1992). Wild (op cit.) observes that failure to use ICT in the classroom is not related to personal ICT skills but to lack of knowledge about classroom use of ICT, while Byard (1995) reports few positive correlations between ICT confidence and classroom usage. Robertson (1997) notes that a permeated approach, in which ICT is introduced via curriculum subjects, is likely to be more relevant, but coherence and progression may suffer. Even where permeation occurs, there may still be barriers to the successful use of ICT in school. As Barton (1996, p. 291) writes: "It would seem that previous IT experience and even good support for personal IT skills are not sufficient to overcome the effect of a department which makes little use of IT in their teaching."

However, whereas university lecturers and school teachers can call on their own subject knowledge and experience in guiding students towards becoming skilled practitioners, they are unlikely to possess the same degree of expertise in ICT (Somekh et al, 1992; Easdown, 1994). Easdown (op cit.) reported that history mentors found it very difficult to discharge their ICT responsibilities effectively because of their own uncertainty and inexperience with subject specific uses of information technology, the problematic nature of gaining access to ICT equipment or the nature of the ICT provision in subject departments. Our experience suggests that this is true of other subjects also. A recent survey at this institution (Opie, 1998) indicated that 63% of our school-based mentors cited lack of training as a major obstacle to their use of ICT. The situation with the students themselves is similar. Wild (1995) reports that less than 20% felt prepared to use ICT in the classroom.

Yet, while the research highlights the problems, it also offers solutions. Wild (op cit.) in his review of the research draws out some key factors in the successful use of ICT in the classroom. Certain strategies stand out: (i) providing teachers on teaching practice with specific responsibilities to use ICT (cf. Davis 1992); (ii) having students working

with children in the training institute (cf. Davis 1992; Downes, 1993); (Hi) having students observing teachers use of ICT with children in schools (cf. Davis 1992; Novak and Knowles, 1991; Handler, 1993); (iv) having a specific teaching methodology for classroom use (cf. Diem 1989; Oliver, 1994; Monaghan, 1993); and (v) modelling the use of ICT by lecturing staff at the ITE institute (cf. Wright, 1993). This paper is primarily concerned with the first of these strategies and its implementation through an ICT Portfolio.

The notion of assessing ICT in the form of a portfolio evolved from previous experience. In the past, despite introducing students to the mathematical uses of spreadsheets, databases, Logo and so on, we found that many of them did not put these ideas into practice. Our first response was to introduce a compulsory assignment which required students to undertake work with children in school using some aspect of ICT for the learning of mathematics. The major limitation of this approach was that it tended to be too narrow. Students become knowledgeable about one area such as Logo and ignored other possible uses of technology. On the other hand, the scope of such technology is now so wide, and the opportunities in school so limited, that it seems unrealistic - at present - to expect them to use each application with children in classrooms, a view that would appear to be endorsed by the Trotter Report:

Teachers will be developing their IT capability throughout their teaching careers, and so it is not appropriate to expect students to have full capability on leaving their ITE. However, it is reasonable to expect that students will by that point have been given a foundation on which continuing IT capability can grow. (DES, 1989, p. 5)

The ICT portfolio represents our attempt at providing such a foundation. This is achieved by introducing the students to nine different applications of ICT during the university-based part of the course. Thus far, we have used a combination of distinct/permeated approaches, the former to introduce the software, the latter to consider how the application might be used in mathematics. In addition, students are required to build up resources in each of these nine areas, whilst providing a written account of the use of two of these applications during their school placements (Appendix 1).

Results

Table 1: Student Teachers use of ICT

Application (Student, School)	Mathematical Topic	Year Group	Set	n	(Sessions , Minutes)
Internet (Netscape Navigator & Internet Explorer) (1, 3) *	Resources for maths	Staff	N/A	5	(1, 50)
Spreadsheets (Claris Works) (1, 4)	Graphical representation of data	Y9	2 of 4	26	(1, 50)
Spreadsheets (Excel) (2, 2)	Number Sequences	Y10	4 of 6	22	(1, 70)
Database (Excel) (2, 3)	Averages & Graphical representations	Y8	1 of 6	30	(1, 70)
Internet (Netscape Navigator & Internet Explorer) (3, 3)	Resources for maths	Staff	N/A	5	(1, 60)
Graphics Package (Omnigraph) (3, 1)	Graphical representation of trigonometric functions	Staff	N/A	6	(1, 60)
Spreadsheets (Claris Works) (4, 4)	Graphical representation of data	Y7	Mixed Ability	30	(1, 50)
Internet (Netscape Navigator & Internet Explorer) (4, 9)	Data Handling	Y10	5 of 9	20	(1, 50)
Logo (5, 10)	2-D Shapes	Y8	2 of 5	34	(4, 50)
Integrated Learning System (Success Maker) (5, 10)	Arithmetical skills	Y10	Special Needs	1	(24, 20)
Integrated Learning System (DLK Mathswork: AreaMate) (6, 9)	Areas of rectangular and triangular figures	Y10	6 of 9	30	(1, 60)
Spreadsheets (Excel) (6, 8)	Data Handling	Y10	Mixed Ability Statistics	15	(2, 58)
CD-ROM (STEPS Maths Factory) (7, 4)	Arithmetical skills	Y7	Special Needs	1	(1, 50)
Spreadsheets (Claris Works) (7, 4)	Number Patterns	Y9	1 of 4	30	(1, 50)
Small Software (Amazing Maths &	Mental Arithmetic & Problem Solving	Y8	5 of 5	24	(1, 70)

Maths Circus) (8, 5)					
Integrated Learning System (Success Maker) (8, 5)	Arithmetical skills	Y9 & Y8	Special Needs	2	(2, 30).
Graphical Calculators (Sharp EL 9400 EL 9600 OHP model) (9, 7)	Graphical solutions to simultaneous (Y10) and quadratic equations (Y11)	Y10 & Y11	1 of 5 Y10 1 of 5 Y11	30	(3, 60) Y10 (3, 60) Y11
Spreadsheets (FireWorkz) (9, 1)	Graphical representation of data (Y8) & use of formulae (Y9)	Y8 & Y9	1 of 4 Y8 1 of 4 Y9	2 gps. of 16 3 gps. of 11	(1, 50) Y8 (2, 50) Y9
Logo (10, 2 & 5)	Angles	Y7a & Y7b	Mixed Ability	28 31	(2, 70) Y7a (1, 70) Y7b
Spreadsheets (Equator) (10, 2)	Maximum area for set amount of fencing	Y10	2 of 5	30	(2, 70)
Spreadsheets (FireWorkz) (11, 1)	Data handling: mean and range (Y8); use of formulae (Y9)	Y8 & Y9	2 of 4 Y8 1 of 4 Y9	2 gps. of 16 2 gps. of 16	(1, 50) Y8 (2, 50) Y9
Graphics Package (Mouse Plotter) (11, 2)	Graphical representation of quadratic functions	Y10	2 of 6	34	(2, 70)
Internet (Netscape Navigator & Internet Explorer) (12, 1)	Arithmetical skills (Virtual Maths. trail)	Y7	Mixed Ability	15	(1, 50)
Graphical Calculators (Texas TI-80) (12, 1)	Algebra, Max-box	Staff	N/A	8	(1, 40)
Integrated Learning System (Success Maker) (13, 10)	Arithmetical skills	Y7	Special Needs	1	(6, 20)
Spreadsheets (Excel) (13, 9)	Iterative approach to percentages	Y8	2 of 6	2 gps. of 6	(2, 30)
Spreadsheets (Excel) (14, 8)	Sampling variation & graphical representation of data. (Y8)	Y8 & Y10	1 of 4 Y8 3 of 4 Y10	26 Y8 30 Y10	(2, 60) Y8 (3, 60) Y10
Graphics Package (Omnigraph) (14, 8)	Questionnaire Design on 'average' pupil & graphical representation of data. (Y10)				
	Graphical representation of trigonometric functions	Y11	1 of 4	3	(2, 60)

* The number pair refers to the student and school: (1, 4) means student 1 in school 4.

Table 1 shoewshow one group of fourteen mathematics PGCE students used ICT in schools in the academic year 1998-99 in the course of completing their ICT portfolio. As can be seen, there is great variation both in the number of participants using the software application and the time spent on it. This variation is perhaps to be expected since we neither specified the time nor the number of participants. However, the variation can be partially explained in terms of the software being used, with for example, spreadsheets tending to be used with whole classes and Integrated Learning Systems more commonly used with small numbers of pupils. The frequency with which the different applications were used is shown in Table 2.

Table 2: Applications used by Mathematics PGCE students in Schools

Application	Number of students using Application	Percentage of total
Spreadsheets	10	35.7
Integrated Learning System	4	14.3
Internet	4	14.3
Graphics Package	3	10.7
Graphical Calculator	2	7.1
Logo	2	7.1
CD-ROM	1	3.6
Database	1	3.6
Small Software	1	3.6
Total	28	100

It would be unwise to generalise from such a sample. However, there are several notable features of this table which are worth commenting on. Firstly, spreadsheets were used to a far greater extent than any other software. Secondly, the use of databases, small software, and CD-ROMs was minimal. Thirdly, whilst it might appear that the Internet is beginning to make some impact in the classroom, it needs to be stated that three out of the four uses above were for staff training rather than with children. Finally, Integrated Learning Systems, although used on four occasions, were not one of the applications that received attention during the university ICT sessions.

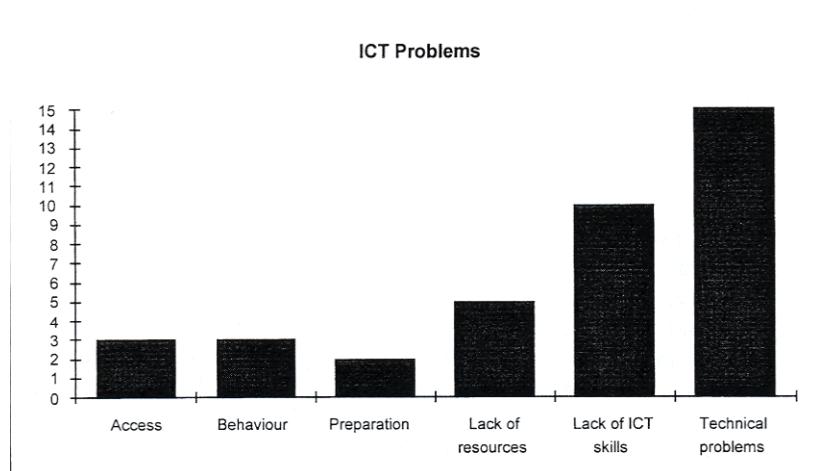
The following analysis is in two parts. The first of these highlights the problems and benefits which the students reported in their use of ICT on schools. These comments were extracted from their written assignments and presented to each student for verification and amendment. The second part consists of the their evaluation of the ICT portfolio itself.

Students' Accounts of their School use of ICT

For ease of analysis, the students' accounts have been separated into 4 categories: ICT Problems, ICT Benefits, Mathematics Problems and Mathematics Benefits, but it is recognised that these categories are not necessarily discrete.

ICT Problems

Planning mathematics lessons which are framed around the use of ICT present formidable difficulties for student teachers. In addition to classroom management, differentiating for individual differences and presenting subject knowledge in novel ways, there are extra barriers of computer skills and technical problems to be overcome. Most likely, these lessons will take place away from the familiar classroom, and so the process begins with a problem of access.



Of the 28 uses of ICT, 22 reported one or more problem with ICT. Three of these said access was a problem; three complained of behavioural problems in the computer room, whilst two wrote of the extra preparation required. Five thought they were hindered by the lack of computers or graphical calculators. However, there

were far more complaints about the teachers' or pupils' lack of ICT skills, and about the technical problems encountered with hardware or software. Typically, these referred to problems with printers not being connected to computers or problems with saving work. It is noteworthy that two students, who said they had no problems, wrote in one case that a technician had set the room up and in another case, the student herself had demonstrated the use of a graphical calculator on an overhead projector beforehand. Writing of spreadsheets, Healy and Sutherland (1990) observe that: "Pupils' first introduction to computer-based activity is crucial." and note that, "There appears to be a minimum level of syntax which pupils need to know before they start to use a spreadsheet." The above results would suggest that there is also a minimum level of preparation required for conducting any lesson based on ICT, which includes familiarity with software, hardware and the computer room set-up. Such extra work may prove a powerful deterrent - unless the benefits can be seen to be worthwhile.

ICT Benefits

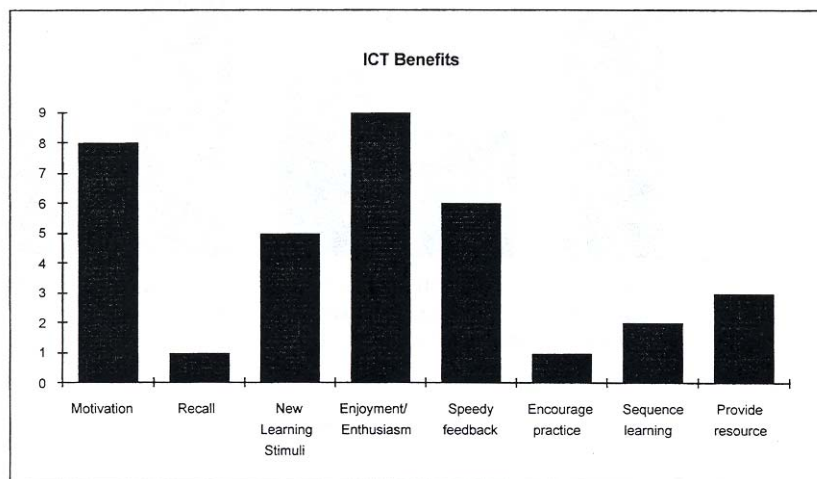


Figure 2: ICT Benefits

According to Rowntree (1982), the functions of educational media are to: engage the student's motivation, recall earlier learning, provide new learning stimuli, activate the student's response, give speedy feedback, encourage appropriate practice. Self (1985) adds another two functions, namely to: sequence learning, and to provide a resource. Of the 28 uses of ICT, 18 contained reports of one or more benefit associated with ICT. Eight of these related to motivation, and this was often linked to the pupils' desire to improve presentation. Five responses fit into the new learning stimuli category; another six were related to speedy feedback; whilst a further nine refer to pupils' enjoyment or enthusiasm. (In Figure 2, 'enjoyment/enthusiasm' is preferred as a category instead of Rowntree's "activate the student's response").

Mathematics Problems

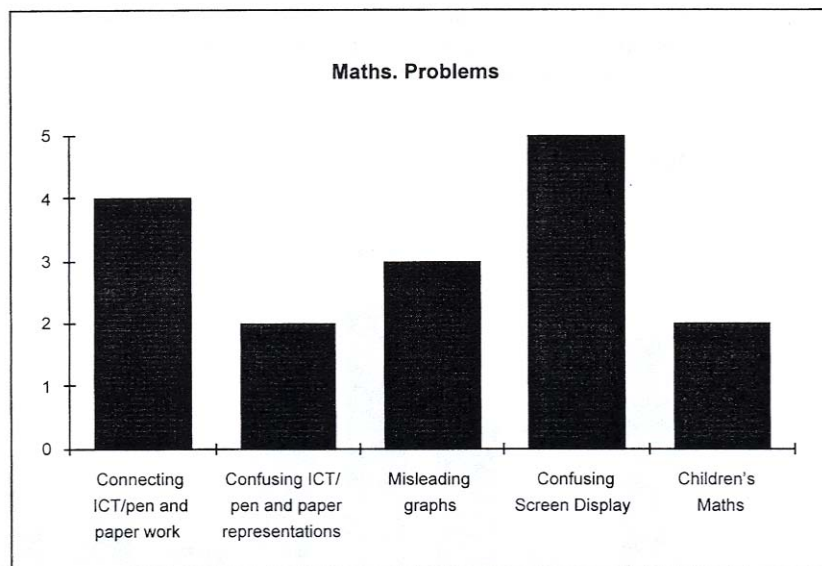


Figure 3: Mathematics Problems

Four students wrote of the lack of connection between computer and pen-and-paper work on the same topic. Two of these were in the form of complaints about the pupils' failure to make connections, but the other two comments seemed to be reflections on the student teachers' own need to relate the two forms of teaching. Several students suggested that there might be some in-built dissonance between computer and pen-and-paper work, writing that there was confusion between the spreadsheet use of formulae and normal algebraic representation. Indeed, one student argued that laborious calculations by hand could better help children see the bonds between numbers. Another said that mathematics teachers might not be aware of the existence of Integrated Learning Systems, since they were often located in the Special Needs department. Three more wrote of difficulties associated with graphs, with one asserting that: "Graphs could be both meaningless and misleading". Five comments referred to the need for children to be able to interpret the screen display or understand the functions of keys. For example, it was said that confusion was caused by computers and graphic calculators using more decimal places than the pupils were accustomed to, or in switching to scientific mode, which was meaningless to the pupils.

Mathematics Benefits

Mathematics Benefits

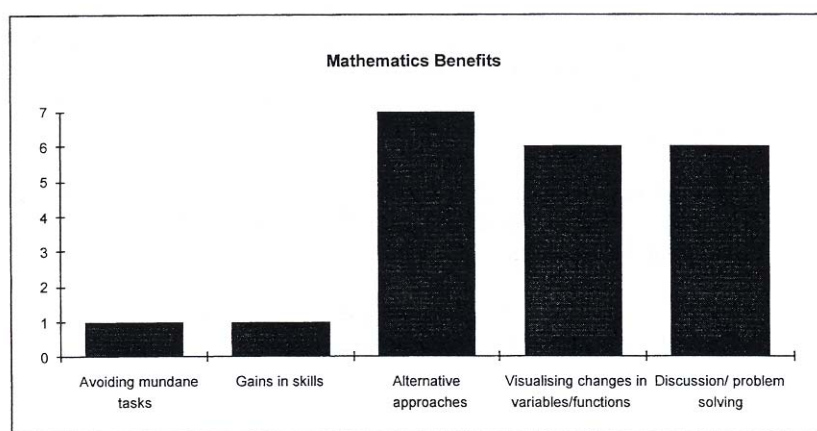


Figure 4: Mathematics Benefits

One student suggested that the mathematical benefits stemmed from the avoidance of low level skills such as those involved in drawing graphs. Another (in the case of ILS) said that there were discernible improvements in arithmetic proficiency. However, the major mathematical benefits seemed to fall into three categories. In the first case, leT was seen as offering new approaches. Typical comments were: "Ideal for iterative approaches to percentages." and "Able to revise about areas of data handling such as scatter diagrams." In the second case, student teachers remarked on the way the computer or graphical calculator facilitated the visualisation of changing variables or functions. Typical comments here graphical representation." Finally, students remarked on the power of the media for fostering discussion or problem solving. One student wrote that:

"In a pie chart displaying pupils' favourite crisps, when asked what would happen if the number preferring Salt and Vinegar increased, pupils thought only that sector of the chart would change." This, she said led to discussion. Another said the computer activity facilitated "What if?" investigations.

Students' Evaluations of the leT Portfolio

Students' evaluations of the ICT portfolio took two forms. Firstly, as part of a general course evaluation, they were asked to comment on the mathematics' assignments as a whole, the ICT portfolio forming one of four such assignments. Secondly, they completed a short questionnaire, evaluating the portfolio in terms of its aims (Table 3). Evaluations were completed by thirteen of the fourteen students who undertook the ICT Portfolio.

Three students made only negative remarks and another three only positive remarks. The remaining seven offered both. The following extracts represent this division.

"This assignment is only useful if you're useless at ICT. Otherwise, its just hoop jumping."

"Perhaps, the assignment should be more essay-based rather than filled with loads of handouts."

"This is possibly the most useful assignment since it has made me think of uses of ICT in the maths classroom. Also, I now have a good source of material for my own use."

"Really useful - an excellent resource for the future. An ideal opportunity to collect and keep ICT related things for use in the classroom. I can think of no better way to fulfil the standards for ICT."

"I think the written tasks about classroom experiences was good and made me think about my professional development. I think the rest of the portfolio is a bit pointless. You pass by having the same handouts as everyone else."

"From what I have seen few maths departments really make use of ICT. The ICT Portfolio has come together a bit slowly for me. It is useful for professional development. Compiling things through the year is a good method of putting this assignment together."

The questionnaire responses were as follows:

Table 3: Questionnaire on the Aims of the ICT assignment

Aims of the ICT assignment	Not at all	A little	Quite well	Very well	Fully	Mean (Median)
	1	2	3	4	5	
1. To ensure that, by the end of the course, you satisfy the ICT requirements for ITT (DfEE, 4/98)	1			6	6	4.2 (Median =4)
2. To encourage you build up your knowledge of ICT in relation to mathematics education in a systematic way.		2	2	6	3	3.8 (Median =4)
3. To utilise your ICT knowledge during your school placements		3	3	3	4	3.6 (Median =4)
4. To provide you with a portfolio of ICT work so as to assist you in your future professional development.	1		2	8	2	3.8 (Median =4)

Conclusions

The above results can be viewed from several perspectives: as a snapshot of current use of ICT in our partner schools; as an indication of how our students think ICT interacts with mathematics teaching; as an account of students teachers' feelings about being required to use an ICT portfolio; and from the point of view of using this means of implementing ICT.

As a snapshot of current use in a small number of schools, this study does not seek to challenge in-depth studies of anyone form of software, whether it be spreadsheets, Logo, graphical calculators etc. Rather, the commentary here is limited to some general observations. Student teachers' comments would appear to add support to the view that the successful use of ICT requires a "minimum threshold" of technical competence with the software (Gardner et al., 1992; Watson, 1993). There seems to be sufficient evidence across the different types of software used in this study to suggest that technical problems constitute a significant deterrent to the uptake of ICT. Insufficient resources is undoubtedly at the root of some of these problems. However, even where resources are available, the use of ICT does not appear to be an integral part of the normal teaching routine. It is suggested here that technical problems may be exacerbated by the infrequent use of hardware and software by mathematics teachers. This in turn can be explained - at least in part - by the reality of a lack of staff training in the use of ICT in mathematics subject teaching. Indeed, on several occasions, our students took on the role of staff trainers.

Despite these impediments, there is a great deal to be optimistic about. The student teachers' reports contain a heady mixture of pupil enjoyment, enthusiasm, motivation and professional presentation. Children, they report, were able to compare different graphs without getting hung up on the intricacies of drawing; they valued the nature of the feedback; and they were engaged and in control of their own learning. Teachers and pupils also appeared to have appreciated the benefits of using ICT as a resource for learning. In several cases, student teachers have acted as catalysts for the uptake of ICT, with schools buying software or graphical calculators as a result of their input.

From the perspective of mathematics, there were also benefits. At one level, these were about speed; the avoidance of mundane tasks, and improvements in arithmetical skills. It was asserted that the software enabled pupils to see how changes in one variable affected changes in another, and several commented on the power of the medium for visualising the relationship between functions and their graphs. At a higher level, the students reported that using ICT had fostered discussion; facilitated investigative approaches; and enabled teachers and pupils to access realistic data. Yet, it was not an unqualified endorsement. The message seems to be that teachers *must first* consider what using ICT will add to the teaching of their subject, and that careful preparation is needed to take account of the subsidiary skills involved.

From the perspective of the student teachers, their written evaluations suggest that they had reservations about the part of the ICT portfolio which entailed building up resources, and they criticised the teaching programme for not

taking sufficient account of their individual proficiencies. On the other hand, it would appear that they appreciated the role of the ICT Portfolio in ensuring that they used ICT in the teaching of mathematics, and in providing a resource for their future professional development. This conclusion is reinforced by the questionnaire results, which indicate that the assignment was successful in terms of satisfying its aims.

From the perspective of the university tutors, the ICT portfolio can be seen as a piece of action research. These evaluations suggest that we can improve our practice by integrating the support material more fully within our teaching, and by taking account of individual ICT strengths. As the ICT portfolio evolves, there will be other questions to be addressed.

Should we specify that ICT be used with whole classes? Should student teachers have to use ICT in both school placements? Should there be a minimum amount of time for such lessons? Should there be a specified number of applications used?

These questions of assessment highlight the dangers and the limitations of a compulsory portfolio as a method of implementing the ICT requirements for teacher education. The dangers are those associated with any assessment-driven curriculum. Students may, for example, come to see it as simply 'jumping through hoops'. The limitations stem - at least in part - from the plethora of ICT software that exists. This year we have added graphical calculators to the compulsory uses of ICT in school, but our current course neither incorporates data logging nor dynamic geometry systems. We need to acknowledge that there are limits to what can be done with ICT on a one year PGCE course, and limits to what can be achieved by an ICT portfolio. Hammond (1994) observes that: "There is almost a common sense view, shared by government, industry and by many parents, that Information Technology is a 'good thing'." This is certainly implicit in the TT A document referred to earlier. Perhaps, we might also recognise the limitations of ICT itself.

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Appendix 1: Assignment 4: ICT in Mathematics Education

The aims of this assignment are:

- To ensure that, by the end of the course, you satisfy the ICT requirements for ITT (DfEE, 4/98)
- To encourage you build up your knowledge of ICT in relation to mathematics education in a systematic way.
- To utilise your ICT knowledge during your school placements.
- To provide you with a portfolio of ICT work so as to assist you in your future professional development.

The ICT Portfolio consists of 9 separate areas of ICT. You are required to use two of these areas in teaching mathematics to children in school. Part A (below) specifies what needs to be done for these two different areas, while Part B outlines the organisation of the portfolio as a whole.

Part A: Structure

For each of the two different areas of ICT that you have used with children, you should write approximately 1000 words under the following headings:

Aim

This should be about 100 words, outlining why you chose the particular aspect of ICT, and what you hoped to achieve mathematically.

Background

This should be about 300 words in length, giving an account of previous work in this area (It is suggested that you use the teacher rather than academic journals for this purpose).

The Lessons

This should be about 300 words in length, giving an account of what you did in school, with whom, and over what period. (For example, this could be a detailed case study of two Y7 special needs pupils using software to improve basic skills, or it could be an account of whole class lessons using spreadsheets to teach about number sequences). Where possible, you should include copies of your lesson plans, children's work and any evidence for the success or otherwise of the lessons.

Evaluation

This should be about 300 words in length. It could include details of the difficulties that you and the children experienced in using the ICT, but the stress should be on how this aspect of ICT mediated the children's learning and your teaching of mathematics. In particular, you should draw out the implications for your future teaching.

A bibliography –

This should be set out according to the guidelines in the course handbook (It is suggested that you use between 4 and 6 short articles from journals such as MicroMath).

The criteria for assessment of your work will be:

1. Have you used at least two different forms of ICT with children during your placements and written up your account as above?
2. Have you constructed the portfolio as indicated in part B?
3. Have you drawn out the implications of using ICT for your professional development.

Part B: Organisation of the ICT Portfolio

Your ICT portfolio must be organised as follows:

- It needs to be in a lever-arch folder.
- It should have a Table of Contents at the front.
- It should consist of 9 sections divided by separators each of which is labelled with its content.
- It should have a one/two page conclusion stating how the use of ICT has affected your professional development.

The sections are:

(1) Word-processing/Design

Examples of worksheets that you have designed;

(Include at least one worksheet for each of the different age groups you have taught).

(2) On-line services

Details of how to access the different services; Examples of the information you gathered.

(3) E-mail/web

Copies of e-mail you have sent and received in relation to your professional development;
Copies of materials which you have gathered from the mathematics PGCE site and other sites;
Addresses for mathematics sites;
Addresses for sites relating to your professional development, e.g. TT A, DfEE, Ofsted.

(4) CD-ROMs

Examples of Professional Reviews of CDs that you have downloaded from the Web;
A list of library/school CD-ROMs for mathematics (with brief details on each);
A short review of a CD that you have used.

(5) LogolBoxer

- General user notes (from university or school) relating this software to a particular computer;

Notes relating the software to mathematics;

Two or three short readings outlining the experiences of others in using this software in the teaching of mathematics.

(6) Software 11-16 and Software 16-18 As for (5) above.

(7) Spreadsheets As for (5) above

(8) Databases As for (5) above

(9) Graphical calculators As for (5) above

Initial Teaching Styles

D N (Jim) Smith Sheffield Hallam University

This ongoing study, developing from Smith 1996, concentrates on the changing beliefs of a cohort of student teachers as they progress through a secondary mathematics Post Graduate Certificate in Education (PGCE) year, with particular regard to the balance of their intended teaching styles across the range of the well known Cockcroft paragraph 243 categories, [Cockcroft, 1982]. It discusses the nature of these changes, as many of the student teachers struggle to come to terms with conflicting pressures from school teachers, pupils, college tutors and their own ideals.

Introduction

This is essentially an action research study in the sense that it is intended to inform, guide and perhaps change the professional practice of tutors on the course. The tutors are committed to use an active learning approach themselves and to encourage student teachers to do so in their own teaching. (e.g. Smith, Jim "Getting Started", 1996). Clearly 'active learning' can be interpreted in a variety of ways;

"A number of phrases have been used to capture the essence of active learning such as learning by doing, learning by experience, learning through action, learning through talk, student-centred learning, peer collaboration and co-operative learning" (Kyriacou, 1992, p.31 0)

All of these aspects of active learning are incorporated into the course and student teachers are encouraged to use these in their own teaching. However, there is often (but not always) an opposing pressure from those school teachers and mentors who adopt a more teacher centred, didactic approach. Pupil management provides another pressure. For some student teachers, struggling with management aspects, there is a strong temptation to provide themselves with a safe and manageable situation through the use of essentially routine approaches to the subject.

Methodology

The research aims were discussed with our 1996/7 cohort of one year PGCE students and their co-operation was requested and obtained. Nine students completed the entire year and the research findings are based only on those nine students, who completed surveys at three points in the year; on entry, half way through the year and during the final session at the end of the year. The surveys were used to identify which individual students were making changes in their views regarding teaching approaches. These particular individuals were subsequently interviewed to obtain more detail.

Cohort

Student Number	Gender	Age	Degree Subject	Own 11-16 schooling	Post-course intentions
1	F	36	Physics	Overseas	Mathematics Teaching
2	M	23	Applied Statistics	Public	Mathematics Teaching
3	M	30	Mathematics	Comprehensive	Mathematics Teaching
4	F	35	Mathematical Sciences	Secondary	Mathematics Teaching or Higher Degree
5	M	30	Control Engineering	Secondary	Mathematics Teaching or Outdoor instructor
6	M	25	Civil Engineering	Middle / Upper	Mathematics Teaching
7	M	42	Manufacturing Systems	Secondary	Mathematics Teaching
8	M	41	Chartered Surveyor	Grammar	Mathematics Teaching
9	F	44	Maths, Computing and Statistics	Grammar	Mathematics Teaching

Survey 1

At the start of the semester, the first taught session focused on the wide variety of ways in which pupils learn and teachers teach, including an analysis of a range of mathematical activity in terms of the Cockcroft 243 categories. During this first session the students were offered the view that problem solving and investigative work employed largely the same concepts, skills and strategies but that problem solving could be thought of as a more convergent activity as it involves seeking a solution. Investigative work was said to be more divergent and a wide range of work could emerge from a single starting point. Examples of problem solving and investigative work were compared and contrasted.

At the end of this first session, students had been asked "On average, what percentage of teaching time do you intend to use in each of the Cockcroft 243 categories of exposition, discussion, practical work, routine practice, problem solving and investigative work?" All of the students were willing and able to speculate on their balance of intended teaching styles. Although no overall pattern emerged, this provided a benchmark against which later changes could be observed.

Students were also invited to consider whether the balance of teaching time would be different for different age pupils. Perhaps unsurprisingly, there was no clear pattern in the responses, with many contradictory views being expressed, except that the great majority of these student teachers expected to do more practical work with younger pupils and less with older pupils. Similarly, the student teachers were invited to consider whether the ability of pupils would alter their intended balance of provision. No clear pattern emerged with regard to exposition, discussion and investigative work. Trends did emerge in other categories though; more practical work was thought to be appropriate for the least able, who also were thought to need more routine practice. The most able pupils were considered to need more problem solving work.

Semester 1

During the rest of Semester I the students undertook 10 weeks of college and school based work, typically 2 days of each week in school and 3 days in college. This was followed by a seven week full time teaching practice in school in which the students were expected to teach 50% of the time, maintain a pastoral role and continue "a whole school involvement".

Survey 2

The students were surveyed again at the end of Semester 1, when it was found that two particular students had changed their views quite dramatically. These changes are described below.

Student 9, female, age 44, whose own secondary schooling had been at a grammar school had delayed going into mathematics teaching after completing her degree in order to start a family. Her initial views had been largely in favour of exposition, practical and practice, but had changed to a much more equable distribution across the Cockcroft categories. Her views on teaching styles appeared to have been influenced in a pragmatic way by the practical experience of teaching in a large comprehensive, claiming

*"Younger children like variety, a small amount of exposition
Followed by practice and problem solving, cannot take in much at
anyone time and need to keep returning to the subject. Do not cover too much in one lesson. "*

This appears to be a response to the pressures and demands placed upon her by the need to manage pupils, maintain their interest and to achieve learning. There is little evidence of insisting on maintaining a particular idealistic approach in the face of the practical obstacles and the description given is that of a fairly conventional mathematics lesson.

Student 8, male, age 41, whose own schooling had been in a grammar school, had initially planned to adopt a high proportion of exposition work. After his Semester 1 placement in an 11-16 comprehensive, he had made a significant move away from exposition and increased considerably the proportion of time that he wanted to allocate to routine practice. He commented

"I still believe exposition is very important, but have found it difficult to keep students interested. "

In comparison to the previous students comments, this is an expression of conviction, and may be something that the student will work towards again during his later career. In a recent review of research on teacher beliefs Fang notes that

"The inconsistency between teachers' beliefs and their practice is not unexpected. Earlier researchers have noted that the complexities of classroom life can constrain teachers' abilities to attend to their beliefs and provide instruction which aligns with their theoretical beliefs." (Fang, 1996, p.53).

Other students made smaller changes, but included the following explanations for those changes that they had made.

Student 1 *"I found that kids learn better when they are actively involved in (the) learning process as a whole class and even weak kids obtain good results. "*

Student 3 *"I value the practical activities and investigative work far more than I did at the start ... "*

Student 4 *"I realise how important it is to use creativity and imagination in planning lessons to motivate and interest the pupils into learning. Spice and variety in the form of employing different teaching styles promotes enthusiasm for yourself and the pupils. The theory of teaching mathematics was not fully understood until practical experience was gained. My views on teaching mathematics have changed considerably since I started the course. "*

Students were asked again to comment on how their approach would vary for different age pupils. This time there was a more coherent overall response with many commenting on the need for older pupils to do more investigative work and problem solving. The increased emphasis on investigative work was explained by perceptions that older pupils were more able to take on the responsibility of investigative work and may also be involved in producing investigative course work at GCSE. The increased emphasis on problem solving was considered appropriate because of the proximity of examinations, which the student teachers perceived to involve considerable problem solving. Many also commented that ability was more of a determining factor than age.

Commenting on the relationship between their intended teaching approach and the ability of pupils, students' opinions had not tended to converge in general. For example some thought that exposition should be reduced for low attainers, but an equal number thought that it should be increased. However, there was very strong support for low attaining pupils to do more practical work, with a typical comment being from student 4

"More practical work with low ability pupils. Keep things simple to understand and interesting and use practical situations. "

Of course, the notion of 'practical work' in mathematics has a variety of connotations including relating mathematics to everyday life, the use of concrete apparatus to model mathematical concepts, the use of real objects, the use of practical measuring equipment, etc. All of these interpretations had been discussed and exemplified with the PGCE students during their college based sessions.

Semester 2

In Semester 2 the students were placed in a different school beginning with 8 weeks in which the students were in school 3 days, college 2 days. This was followed by a full time block practice in school of 8 weeks at 75% of

timetable, with a final day in college during which the third survey was conducted.

Survey 3

Perhaps unsurprisingly, in general there were smaller changes in views as a result of the second half of the year.

The major exception to this was student 6 who had made little change during Semester 1 and then made major changes in Semester 2. The effect of these changes was to move away from a heavy emphasis on routine practice towards a more equitable distribution across the Cockcroft categories. This student was interviewed and reported that his initial ideas, as one might expect, had been based upon his own schooling. (Interestingly, at the time of the interview he had just been appointed to a teaching post at the same school that he had attended as a pupil and was able to comment on the changed teaching styles now adopted under a new Head of Department). During the first placement he had been influenced by the example of two particularly enthusiastic teachers, who had done some joint planning and teaching of lessons with him. The student had been relatively unaware of the strength of this influence until the second placement, when he had an opportunity to follow the role models that the two teachers had provided. Indeed in the second placement the student had gained sufficient confidence to say that although the head of department "was the best teacher", the HoD spent "too much time talking to the class" and not enough time on other Cockcroft 243 aspects.

In the final survey, students were also asked to comment on the difficulties faced when trying to implement their ideal Cockcroft 243 balance in practice. Six of the nine students independently commented on aspects of taking over from other teachers (this is a similar finding to Sinkinson, 1996). These ranged from the relatively mild difficulty of student 2:

"Initially the pupils were obviously used to the previous teacher and so some time was taken getting used to the change. "

through to the more serious issues of student 3 who commented

"Children were used to their class teacher and resented any alteration, this caused some behavioural problems. "

In further discussion with student 3 it appeared that he had felt obliged to adopt two different styles so as to emulate the two very contrasted teachers who shared the teaching of one particular class;

"It was a nightmare; pupils didn't know what to expect. I'd have to behave very strictly on Wednesday and very relaxed on Thursday!"

Students were again asked about their views on how age and ability might affect their provision, with very similar results to the previous survey, except that there was an even stronger view that low ability pupils require more practical work.

Reflections and Conclusions

For the group as a whole I am concerned that some intended messages from the college did not get across (e.g. need to reduce formal didactic exposition for lower ability pupils) . It was interesting to observe the convergence of views over age related approaches, but some concerns are raised by the lack of convergence on ability related approaches (except on practical work).

The changes made by individuals seem to follow a pragmatic line, responding to the situation as student teachers find it in practice. However, some students make such changes happily and consciously, acknowledging their initial lack of background knowledge. Other students make such changes pragmatically, but reluctantly as they conflict with their strongly held views on the nature of the task. This bears comparison with other studies, e.g. a study of student teachers implementation of investigative approaches (Cooper, B. 1990) where strongly held views about the correct nature of mathematical education persisted through the PGCE year.

The issue which emerged as the most significant for me personally was that of the relationship between the student teacher and the various classroom teachers from whom they were temporarily taking over. The particular aspect that caused difficulty was the student teachers frequent attempts to emulate the normal class teachers style and approach. At best this can be an emulation of a range of effective styles, at worst the student is trying to emulate a range of conflicting styles and sometimes attempting to do so with a single class. I believe that student teachers need to be encouraged to learn from other teachers, but also need the freedom and encouragement to experiment and begin to develop their own style.

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Connections

Melissa Rodd University of Leeds

This description/analysis of a secondary mathematics PGCE session is a case study about mathematics PGCE-teaching practice. The session described and analysed was called 'Preparing for rich mathematical activity' and was taught towards the end of the one-year mathematics PGCE students' course at the University of Leeds in 1999. The aim of the session was to increase the student-teachers' teaching repertoires to include problem-solving activities based on pupils' conceptual problems with National Curriculum (DfEE 1995) topics.

Investigation of how we teach prospective mathematics teachers is timely: here in England in the late 1990s we have had an extensive teacher preparation curriculum incorporating explicit Standards for assessment (DfEE 1998) and the schools mathematics curriculum has been heavily influenced by the revival of the importance of arithmetic and associated mathematical understandings under the 'National Numeracy Strategy' (DfEE 1999). The language used to describe those who have the responsibility for the preparation of new teachers suggests teacher preparation is a behaviourist commodity: *initially teachers* are to be *trained* by *providers*.

Within 'Partnership' PGCE schemes [The focus in this paper is on preparing graduates to teach mathematics in secondary schools] (DfEE 1992), the HEI tutors do not usually have direct responsibility for student-teachers' progress in school, but are wholly responsible for preparing-to-teach mathematics sessions at the HEI. It seems, therefore, appropriate that to try to understand what it takes to teach prospective teachers we should start by looking at what we have most control over, i.e., these HEI maths sessions.

The paper starts by giving some background on the overarching theme of 'connection'. This theme is used as an organising principle for the description of the session, which follows. In this section on *the explicit* plans for the session, I describe the aims of the session, how it was planned and a little of what happened. Then in the section on *implicit* guiding principles, I raise some issues about appropriate methods of analysis of mathematics teacher-educator pedagogy and then present the three theoretical notions (pedagogical Content Knowledge (PCK), teacher learning, identity), and their mutual connections, which underpinned my conceptualisation of the PGCE session in question.

'Connecting' in PGCE session design

In order to write about a mathematics PGCE session, I needed some organising principle or themes. The one that will be used in this paper is that of 'connecting'.

Confidence with connections in mathematics underpin fluent teaching. For example, success in teaching square numbers 'off the cuff' may occur when areas of square shapes are related to these numbers; a *connection* between shapes and numbers is 'available' for representation. The importance of a teacher's ability to make connections between different aspects of mathematics was found to be more significant than their 'mere' depth of content knowledge in assessment of teacher effectiveness (Brown *et al.* 1997). Having a rich repertoire of pedagogical representations, in the sense of Shulman, requires 'mathematical connectionism' (i.e. understanding relationships within mathematics, e.g. that fractions have decimal equivalents but some decimals cannot be expressed as fractions, that transformations which yield symmetries have structures). So, clearly, connections are important in mathematics and in teaching mathematics and, as I intend to illustrate, also in mathematics PGCE session design.

[Many of the ideas about 'connecting' came from discussion with Liz Bills.]

Before focusing on a specific PGCE session, a brief analysis of the concept of 'connection' is appropriate: 'Connection' is the paradigmatic noun from a class of metaphors which include others like 'link', 'progression', 'relation', 'transmission', 'chain', 'engage' etc. Lakoff and Johnson (1980) suggest that 'metaphor [is] a principal vehicle of understanding' (p160). In this spirit, 'connectionism' signals a conceptual outlook which, may be helpful for developing understanding of how HEI tutors might plan for student-teachers' learning. This particular metaphor can serve as a suitable meaning-making cognitive instrument (Ortony 1993) in devising teacher education programmes. The overarching aim of 'connecting' is particularly relevant to PGCE tutors as PGCE sessions are often multi-level experiences. For example, within a session, students may work on some mathematics then plan teaching that mathematics which includes planning to test out theories of teaching. Organising such a session requires the tutor to be able to conceptualise these levels and design tasks for the students to make sense of the connections between them.

The metaphor of connection is used within an area of current research in experimental psychology and cognitive science (Bechtel and Abrahamson 1991, Bereiter 1991) inspired, perhaps, from advances in AI (e.g. Harre 1996). The human brain is conceptualised as a complex network of nodes and connections and these, in some sense, underpin human cognition. From this perspective, thinking about the mind has shifted from a post-Piagetian 'constructive' capacity to the processing capacity suggested by connectivity. In teaching, the twin processing aspects of implicit and explicit reasoning (Tomlinson 1999) are essential; action and reflection are mutually symbiotic. This implicit-explicit dialectic is also important in teaching teachers.

The connectionist metaphor is used within educational discourses increasingly. This was predicted by Bauersfeld (1994) in the mathematics education context and interpreted by him to favour a culturally-sensitive, experiential, meaning-negotiating pedagogy (p 144). In the ITT NC (Initial Teacher Training National Curriculum) for England and Wales (OfEE 1998) Annex G, for secondary mathematics ITT, there are many implicit or explicit instantiations of 'connection'. Examples vary from the explicit pedagogical notion of 'pupil progression' (section A p 105), the explicit mathematical one of 'establishing connections' (B,6,a, vi, pi 09) and the mathematically focused notion of 'relations' (e.g. A,3 pl07), to the use of words or phrases like 'communication' (A,I,a,iv, pl05), 'links' (B,6,a,iii, pl09) and 'chains of reasoning' (B,8,c,iv, pl12jo. A question for the reader to muse is, given the existence of connectionist metaphors in the ITT NC, is Bauersfeld correct? That is, does (or could) the ITT NC promote teaching where meanings are negotiated, where learning stems from pupil activity and cultural awareness is valued?

[9 "the next catchword - connectionism" (Bauersfeld 1994 p141)]

[10 Other metaphors are also used: for example, the construction metaphor is employed as intrinsic to the nature of teaching (understanding is 'built upon' (B,6, pl09».)]

On 'preparing for rich mathematical activity': explicit plans

Like many PGCE sessions, this session was intended to be a multi-level learning experience for the student-teachers. In this section, I start by giving a description of my motivation to run the session, then explain what my session-design tools were and give a taste of the content with some results.

Purpose of the session: my aims

This session, in June of the PGCE year, was planned as a result of having seen all my personal tutees teach adequate lessons but ones which were mostly restricted to 'exposition and practice' style. I experienced being in classes where the tasks offered the pupils were adequately managed and 'delivered' but rarely, in my appraisal, engaged the pupils mathematically. The pupils did questions, got answers and were pleased when their answers tallied with the teacher's. My challenge was to plan and run a session to help the student-teachers to teach lessons which helped pupils to 'engage' more with the mathematics. How to do this? I reckoned a 'direct' approach (like lecturing that there was 'too much exposition and practice!') would be unlikely to be successful in my aim of helping the, by then, almost Qualified Teachers develop their PCK. That a teacher's repertoire should more extensive than what I had seen is (even) an ITT NC requirement, for example:

Annex G,

A 1 (a) All courses must ensure that trainees are taught that pupils' progression in mathematics depends upon teaching which emphasises that mathematics

11. is intriguing and intellectually exciting and can be appreciated by pupils of a wide range of ability as an activity in itself

(DfEE, 4/98)

Annex G goes on to require, for example, "purposeful enquiry" (B 7 ii), and "teaching pupils to think mathematically" (B 8 c). Hence, as an ITT 'provider' I had to find a way to teach our student-teachers that pupil progression is enhanced by intellectual excitement, purposeful enquiry and mathematical thinking as part of their curriculum entitlement.

Explicit plans and the tools used to realise these plans

I wanted to make changes in my students possibilities in practice. So I looked back to learning situations in my experience which had changed my outlook on how to teach for learning. The key principles which informed my thinking in trying to solve this 'how -to -teach' problem were:

- engaging with mathematics as a teacher is important if you want the pupils to engage
- intriguing activities engage pupils
- everything mathematical can be intriguing

The first of these principles - if you teach maths, do maths - has been part of my way of thinking, at least since undergraduate days where a particular teacher (Hung-Hsi Wu) impressed me with the way he used his 'mathematical being' in teaching us. In the session, the students started by getting involved in some mathematical problems at their level in order to stimulate the feeling of mathematical engagement. I found a nice aphorism in Banwell, Sanders and Tahta (1972) which I felt expressed more than my principle (but included it):

The most important lesson preparation is to prepare oneself (P5)

The further practice of this principle was worked on in the session using a 'function game' (ibid. p 42).

For the second of the principles, I used the rationale and approach of Better Mathematics (Ahmed 1987):

.. mathematics is effectively learnt only by experimenting, questioning, reflecting, discovering inventing and discussing. Thus, for children, mathematics should be a kind of learning which requires a minimal of factual knowledge and a great deal of experience in dealing with situations using particular kinds of thinking skills. (ibid. p16)

Rich mathematical activities should enable all pupils to become engaged in motivating and challenging work (ibid. p22)

I had first been introduced to the 'LAMP' project (the early 1980s precursor to the project in the 1987 book) as a PGCE student (by John Backhouse). The whole idea that mathematical thinking was possible for all, not just for 'clever' pupils, has been hugely important to my outlook and practice from then on. My emphasis in this session was to be with 'ordinary' pupils and so discussion turned to what was a 'rich activity' suitable for a KS3 pupil working on some National Curriculum topic.

This brought me to the third principle - nothing in maths is boring - which was inspiringly worked on by Marion Walter at some ATM conferences (the principles of which are in Brown and Walter 1981). Marion showed how even the most tedious-seeming practice question could be turned around, played with and presented to pupils for satisfying enquiry. I wanted to teach the student-teachers some of her techniques.

Content of the session

After having introduced and worked on the three sources mentioned above, my plan was that the student-teachers should work on developing their own 'rich activities' using the problem-posing techniques of Brown and Walter.

Specifically, I asked them (in groups) to think of particular problems their own pupils had had in a lesson they had taught. I asked them to share, within their groups, situations where the pupil had become stuck and they had not been able to offer anything other than an instrumental explanation (which might have allowed the pupil to follow steps but not to accommodate new ways of thinking). Then, within groups, they were to choose one of the problem scenarios and devise 'rich activity' to teach the topic item. The results of all the groups' work were shared towards the end of the session. Here is an example from one group of students:

Topic: trigonometry.

The specific pupil problems considered:

- o not remembering whether TAN is OPP/ADJ or ADJ/OPP
- o not relating TAN to an angle rather than to the size of the right angled triangle.

The student-teachers' 'rich activity' based on problem posing was: ask pupils, working in groups,

- to make sets of (right angled) triangles with a given attribute (e.g. 30 degree angle, 20 cm hypotenuse).
- to calculate various ratios of pairs of sides
- to make observations and hypotheses
- to present the findings of their collection of triangles to the whole class.

The overall student evaluation of the session was that it was considered 'useful'. The weakness was that it had come too late in their course to go back into school to test out the materials which they had devised.

On 'preparing for rich activity' session: implicit guiding principles

On analysing

The MER challenge asks 'what do you do?' and 'why do you do it?'. The aim being that by giving specific session details and theoretical underpinnings for choices in design, a closely woven theory-practice picture should emerge. Being challenged to explain 'What?' and 'Why?' a mathematics education session was designed and run as it was after the event, stimulates a further level of reflection than was actually part of the planning and teaching of the session. This further level of reflection is analogous to the reflection asked of an experienced school teacher 'mentor' whose

'craft knowledge' is opened up in post-lesson conversations with a student-teacher (Haggart, Bum and McIntyre 1993 pp 71-82). How far does this analogy go?

The experienced teacher articulates her "thinking behind actions", her aims and how conditions impinged on her teaching (*ibid.* p 82). In our case, we are trying to find out about the nature of maths-PGCE-tutor 'craft knowledge' by a self-initiated 'opening up' as the teacher of the PGCE class. Whether the analogy is apposite or not depends on how 'context' is understood in the two situations: (1) of a school-teacher 'opening up practice' for student-teachers¹¹ and (2) of an HEI tutor 'opening up practice' for peers. In the former case, the school-teacher tries to make her tacit knowledge explicit (*ibid.* p 72); her understanding of the school context is the source of her explanations to the student-teachers about her teaching actions. For an HEI tutor, the sort of reflection required includes an understanding of various theories and how they inform session design. This making explicit of our understanding of theoretical underpinning is akin to the school teacher's articulation of school-context understanding. Our HEI tutor-context includes understanding and application of theory and, naturally, the connection between these.

Unearthed theories

I had perceived a problem of students' uninspired teaching repertoires. At face value, my aim was to increase their repertoires by teaching them mathematical-task design techniques. I used various principles to design the session as explained in the section on 'explicit plans'. Analysing the planning and teaching retrospectively, the implicit influence of three major theoretical notions can be also discerned. These are:

- 1) pedagogical content knowledge for secondary mathematics
- 2) theory and practice relationship in teacher education
- 3) identity and development of teacher persona

This is where the 'connectionist' image is evident again. Within the session, these themes were implicit and entwined. I will refer to each in turn below, but here is a brief synopsis of their symbiotic function:

I used the student-teachers knowledge about their pupils as a 'source' (see below) of their acquiring their maths PCK (1). This 'knowledge of pupils' includes having a responsibility for their pupils' learning which is intrinsic to a teacher identity (3). Their acceptance of novel approaches to teaching (incorporation into their PCK), given a teacher persona, requires these approaches to be considered realistic in the teaching context in which they were developing (2). I shall now try to make explicit the theories used in this brief conceptualisation.

[1] School-teachers have also opened up their practice for researchers. For example, Brown and McIntyre (1993) devised methods of accessing successful school teachers' knowledge of their teaching.]

On secondary mathematics PCK

As mathematics PGCE tutors, our job is to teach our student teachers mathematics PCK i.e. so that they are able to 'transform mathematics to present it for instruction' in Shulman's terms. The MER challenge is to explain how we 'transform PCK and present it for instruction'. In order to try to explain this transformation in the case described, I found useful the notion of 'sources' of PCK as explored by Ruhama Even and Dina Tirosh with their pre-service secondary mathematics teachers (Even and Tirosh 1995). In their article Even and Tirosh outline recent developments in teacher education which emphasise that the teacher has responsibility to teach pupils mathematics (rather than merely administer schemes or manage classrooms). Hence mathematics-specific PCK is of central importance in the preparation of teachers. So Even and Tirosh ask 'what are the sources of mathematics PCK?' One such *source* is teachers' knowledge of pupils. They note that this source of PCK was part of Shulman's mid-eighties conception of PCK and their paper communicates their investigation of its nature in a secondary mathematics context. In their research, Even and Tirosh presented Almost Qualified Teachers (from eight US colleges) with (made up) scenarios of a literature-based selection of pupils' errors. The specific PCK they tested their subjects for was whether they had knowledge of *what* common pupil errors are and also whether they had knowledge of the possible reasons *why* a pupil might make such an error. They were able to distinguish the student-teachers' *knowing that* the pupil had made an error from their *knowing why* that pupil may have erred.

In planning the session, one of my starting assumptions was that the student-teachers would have knowledge of their pupils' mathematics. An important planning-connection for me was to use this knowledge to develop my students' PCK.

Testing theories within practice

In Even and Tirosh's research, the student-teachers were not needing to uncover the reason for a pupil error at a personal or professional level; they were being tested on their ability to recognise certain form errors and to give

explanations for those pupil errors they spotted. I am not surprised, given this approach, that 'very few' of them 'tried carefully to examine the [pupils] ways of thinking' (p16). In contrast, when my student teachers (also Almost Qualified), were asked to present examples of pupil error (or misunderstanding) they were readily able to come up with examples and suggestions for the pupil's problem. They *saw what* was wrong and they could suggest *why* it was wrong. Where they were stuck was on *how* to teach the pupil so s/he could understand in future. By connecting them with a practical problem which they had not yet solved and offering a plausible theory, it is likely that the student-teachers would be motivated to test out this new approach and from there make reasoned decisions as to their future practice.

PGCE session designers have (at least implicit) notions of how studentteachers learn. The theory which I was (at the planning stage, implicitly) relying on was that which underpinned the Oxfordshire Internship Scheme (with which I had been involved). From this theoretical perspective, student-teachers

"will make their own judgements about what matters in teaching and about how best they can teach. Our long-term influence upon them can be greatest not so much by trying to persuade them of the merits of various practices, but rather by helping them to make their judgements rationally and realistically." (McIntyre, 1988, pp 1 06-7)

So in the context of preparing graduates to teach mathematics, my aim was to bring the testing of theories as close as possible to their experienced practice (see, also, Linda Haggarty's study of mathematics studentteachers' learning within this scheme, 1995). Specifically, my aim here was to 'get them to see' that they needed more tools of the trade, to present some tools for them and to get them to try to solve the problems that they had presented early in the session with the tools. Thereby developing their skills and giving them some practical resource at the same time.

Identity

One of the important underlying themes which I used in planning this session was that of their self-conceptions as secondary mathematics teachers: their identity as practitioners. This session was in the last taught week of their course. At this stage, I assumed that they had developed teacher personas, which I conjectured would include a sense of responsibility for their pupils' learning. I wanted to use their skills in pupil assessment together with their own self-evaluative insights to draw them emotionally in to the scenario of when pupils just don't 'get it'. In other words, assuming that they had taught some topic at some point which they had assessed had not been grasped by some pupil, I wanted to use their dissatisfaction with this situation – however inevitable it might be – to motivate them to engage with another approach to teaching.

In the recent writings of Etienne Wenger (1998) I have found a thorough development of this important 'identity' theme. The theory offered in his book explains my intuitive connection of practice with identity through a "social theory of learning [which is] ... inseparable from issues of practice, community and meaning" (p 145). Indeed, Wenger says himself "there is a profound connection between identity and practice" (P149). Wenger goes on to discuss "negotiability of a repertoire" (p 153) which is possible when personal participation in the practice is sustained. As student-teachers evolve into practitioners and become part of the 'community of practice', their learning will become increasingly practice-orientated (see the section above) and new ideas will need to yield direct classroom benefit. The part of the teacher identity which was used in the session was that of responsibility for pupil learning and investment in the development of pupils' learning and what was offered was a way of working which claimed to offer this direct classroom benefit.

These 'unearthed theories', although familiar to me before designing the session, were not used in my explicit session-planning. On reflection, they seem to be more fundamental than the explicit principles used.

Finally

I have written this description and analysis of a mathematics PGCE session as a practitioner in mathematics teacher preparation. My initial intention was just to share the how the organising principle of 'connection' was a useful metaphor both for planning and for describing PGCE sessions and to exemplify this with reference to the 'planning for rich activity session'. However, the process of reflection and further reading has unearthed further guiding principles which were *implicit* (at the time) in my session design. Following on from that, this raises the issue of what is an appropriate methodology for accessing the "substance and logic" (Brown and McIntyre 1993 pi 09) of mathematics teacher educators.

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