Full Report of Research Activities and Results

Background

An important component of Government education strategy is the need to support teachers in their use of information and communications technology (ICT). Considerable research on students' understanding of aspects of mathematics using ICT exists but teachers' ICT practices in mathematics classes is a relatively unexplored area. It has been suggested that a threshold exists, of frequency of use and over time, for the contribution of IC`T in student achievement in mathematics lessons to become apparent. These factors formed the impetus for the present study which focuses on secondary teachers' practices as they endeavoured to make regular[1] use of ICT in mathematics lessons over the course of one school year.

How does use of ICT affect teachers' lesson planning, classroom interactions and use of written support materials? Does ICT use threaten teachers' technical or mathematical authority? What factors create tensions for them and how do they address these problems? Researching these questions requires immersing oneself in the life of the school, gaining the trust of staff and students and gaining an understanding of variations in the usual preparation practices of teachers. To capitalize on the insights of teachers the project used school-based teacher-researchers[2] to collect data to complement that collected by university-based researchers.

A great variety of software is used in ICT mathematics classes. To keep a sharp focus to the study attention was restricted to ICT tools which allowed a variety of numeric, algebraic and graphic approaches to mathematics. This focus is consistent with the main ICT suggestions in the Mathematics National Curriculum and for A-level mathematics. In order for the classroom activities to reflect real decisions of the teachers and to ensure regular ICT use, teachers chose the tool(s) they used.

The main focus of the research was the teachers. It was considered, however, that researching teachers' practices without regard to their students' learning or attitudes was misplaced. A secondary focus was thus the students in project classes.

The initial intention was to examine five teacher pairs (10 teachers) in five schools. It was anticipated that some teachers would withdraw from the project, so 13 teachers from seven schools were recruited. However, no teachers withdrew. Appendix 1 provides summary information of the teachers, their schools, their project classes and the ICT tools each class used.

Objectives

The research objectives were to investigate aspects of teaching and learning over sustained periods with ICT in upper secondary mathematics classes. The foci of the research were:

[1] A working definition of 'regular use' as 'block or serial whole class ICT-based lessons of not less than 20% of lessons over a period of one term' was given in the original bid. Teachers initially worked towards this. By the end of the project the usefulness of the term was questioned.

[2] Teacher-researchers are, for brevity, hereafter referred to as teachers.

(1) Continuity and change in patterns of teaching and learning
(2) Teachers' preparation and use of resources
(3) Teachers and students' attitudes and teachers' confidence

With regard to (1) it was recognized from the outset that this is such a large domain that there is an inherent danger of superficial analysis. Relevant data were sought from student performance on specific tasks, student records and classroom observation, including video analysis. Attempts at monitoring learning encountered difficulties which are detailed below.

With regard to (2) it was expected that teachers would plan ICT lessons in much greater detail than they plan non-ICT lessons. But what form(s) does this take and does this change as teachers become used to ICT-based lessons? Further to this how do teachers use/design written support materials.

With regard to (3) the study used qualitative methods to access teachers' attitudes and beliefs and largely quantitative methods to access students' attitudes and beliefs.

Methods

Setting the scene

The project sought to describe accurately the ICT practices of ordinary[3] teachers as they planned and engaged upon ICT work with their classes. A secondary focus was the impact of this work on their students' learning and attitudes. Data were collected by teachers and university-based researchers. It was assumed that the two categories of researchers would have different goals and interpretations and that neither has priority over the other.

Data were sought that would inform:

- the contexts the teachers worked in, their personal and institutional histories
- their planning and use of resources
- classroom practices
- student learning and attitudes

The personal and institutional histories of the teachers were compiled by interviews with the teachers and senior staff in their schools and informal regular discussions. Details of teachers' planning and use of resources were obtained from teachers' weekly journals, interviews and informal regular discussions. Accounts of classroom practices were obtained through classroom observation and an analysis of video-taped lessons. Indicators for describing student learning and attitudes were student performance on specific tasks, school records and responses to attitude questionnaires.

Teachers appropriated their own research aims distinct from the formal aims of the project. The question arises, was this action research? The answer is not simple. The activities and reflections of several of the teachers certainly had an action research element to them. However, given that the original aims, objectives and data collection methods were adhered to, it would be misleading to describe this as action research.

[3] Non-pejorative use of 'ordinary'.

The expected timetable for the project was:

- Phase 1, April - August, 1998. Identification of teachers. Induction of research assistant. Meetings with teachers (to include training in classroom observation techniques, trial observations exercises, identification of inservice training (INSET) needs. Piloting and revision of questionnaires and interview procedures.
- Phase 2, the 1998/99 school year. INSET delivery. Detailed planning of ICT-based lessons. Development of student tasks. Data collection: classroom observation; teacher journals; teacher interviews; student questionnaires and interviews; student tasks. Completion of data collection by June, 1999.
- Phase 3, December, 1998 - November, 1999, analysis and report writing. Analysis of discrete units of data collected as they are completed. Completion of data analysis in November, 1999.

NB Difficulties were encountered in INSET delivery and the design of student tasks. Other than this the project carried out these tasks to the allotted timescale. Difficulties in the design of student tasks are discussed in the 'student learning and attitude' section below. Difficulties with INSET are discussed now.

The project was never conceived of as researching the effect of ICT INSET on teaching. INSET on the use of ICT for teachers was, rather, seen as a method of providing support for teachers. An early activity of the project group was a day devoted to familiarization with software packages. It was intended that this would be followed by work in project schools relevant to their specific needs. This was not done because the teachers expressed confidence in their ability to proceed without this. In retrospect this was regarded as a positive decision since the practices of the teachers may be said to their own rather than the ideas of the award holder.

The contexts the teachers worked in, their personal and institutional histories

Teachers bid to be involved in the project. These bids provided some personal details. University-based researchers visited each teacher/class on at least four occasions. There were six extended meetings of the project team. Each teacher was interviewed in the period December, 1998 to January, 1999 and at the end of the school year. The first set of interviews had a schedule of 23 items which included: teaching experience; degree details; ICT competences; questions on mathematics, ICT, teaching and learning; departmental views; classroom ICT work; lesson planning; use of resources; attitude; confidence; significant events. Extracts from video-taped lessons were viewed as a basis for discussion. The interviews were audio-taped and transcribed. The second set of interviews were used to clarify ambiguities in data collected and to discuss teacher end of project reports.

Interviews were also conducted with the Headteacher, the ICT Coordinator and the Head of Mathematics, in each school. These interviews were designed to gain information on ICT provision, present and future intended role of ICT in School/department plans and indicators of the centrality of ICT to the ethos of the school. The interview schedule had 16 items which included: personal details, views on ICT in teaching and learning; whole school/department ICT policy and model (theory and practice); ICT resources; preparedness of staff and foci for

ICT staff development; centrality of ICT to school ethos; response to Ofsted report; involvement in local and national projects.

Teachers' planning and use of resources

Issues concerned with planning and use of resources were discussed during visits to schools, interviews and project group meetings. In addition each teacher kept a weekly journal which included relevant lesson plans and course materials used. An early meeting of the project group discussed the format of these and it was decided that teachers would use their own design. Some used a self-designed proforma whilst others kept a diary. Although some teachers occasionally fell behind with these and collated reports and materials used at the end of a month, all the teachers provided apparently accurate records.

The journals provided a rich source of data on lesson planning (including time taken planning lessons), materials used (textbooks, commercially produced ICT material or self designed worksheets), student activities and lesson evaluations. Given the project ethos that neither category of researcher has priority over the other the reliability of these journals was not examined. However, the close contact between university-based researchers and teachers established a means for the award holder to be confident on the authenticity of these journals.

Classroom practices

Teacher pairs (12 of the 13 teachers in six schools) observed each other teaching. The purpose of this mutual observation was to raise teachers' awareness of issues in classroom observation and to generate an agenda for self evaluations in weekly journals. The number of observations varied. Two contrasting observation schedules were given out and discussed at the first meeting of the project group. One had prescribed areas for comment, the other was an open response form. Teachers preferred the open response form.

Each teacher was to be video-taped with their project class four times during the year: an initial baseline non-ICT lesson and three ICT-based lessons at an early stage, a middle stage and towards the end of the project[4]. This was considered important because of claims that teachers who move to incorporate ICT into their lessons exhibit a partial shift in their roles from manager to fellow investigator and that their students exhibit a partial shift in their roles from follower to task setter.

There are at least two problems with video-taped lesson observations. No lesson observation can observe everything, there must be a focus or a small number of foci. The lens of the video-recorder takes in less than the naked eye. The advantage of video-taped recordings is that that which is recorded can be scrutinized. The primary focus for anaylsis of the video-taped lessons in this project was the teacher: what s/he said and who they said it to. The teacher wore a cordless microphone and the camera, which was static and placed at a corner of the room, followed the teacher's movements.

An established method of coding dialogue in mathematics lessons is the Systematic Classroom Analysis Notation (SCAN). In this coding lessons are composed of activities, e.g. teacher

[4] This happened for all but one project class. The exception was teacher B(2), see Appendix 1. The work his class was doing (A-level mechanics) in the third term of the project year did not, in his opinion, lend itself to ICT-based work. As a result no final video was made.

exposition. Each activity contains episodes, e.g. teacher explanation. What teachers or students do are called events. Events may be described linguistically, e.g. confirm answer is correct, or in terms of what is done, e.g. perform calculation with close direction. The award holder and the research assistant amended SCAN to suit the purposes of this project. Further information is provided in Appendix 2.

A proforma was designed for coding video-taped lessons. The lesson was subdivided into 30 second 'slices' and three rows recorded teacher activity, student activity and episodes (with event descriptors and qualifiers). The award holder and the research assistant conducted repeated independent coding of 10 minute video extracts until they achieved 85% agreement after which the research assistant coded all videos. Teachers were given the opportunity to comment on the reliability of the analysis for their lessons.

Student learning and attitudes

Teachers provided full details of records for project classes and, when applicable, for comparison classes in the school. These included results in national and school set tests. These records did not allow for a statistical analysis of the performance of project class students due to variation in students ages, attainment levels and courses of study.

It was anticipated from the outset that quantifying student learning would be difficult. Apart from the difficulty of defining what learning might be, the following difficulties were anticipated: a test is too narrow; a test is too easy/difficult; a test tests something other than that which it is intended to test; students are 'test-wise' to certain types of tests. The last two difficulties were considered the principle difficulties. Possible ways of addressing these difficulties are: relate the test results to another test of the same area but tested in a different manner; relate the test results to test results from a different area collected in a similar manner.

A further difficulty is that the different ages, attainment levels, courses of study of the project classes and mathematical topics studied meant that most classes would have different tests. These issues were discussed with teachers and there was agreement that, apart from the two teachers with Year 11 classes, they would each submit four draft tests to the award holder. Two of these tests would focus on a topic their students encountered in ICT-based lessons. One of these would be a paper and pencil test, the other an ICT-based test. The other two tests would have the same two forms but cover related topics not encountered in ICT-based lessons. There were problems with this that are dealt with in the results section.

Student attitudes were examined by a questionnaire, see Appendix 3. The questionnaire was based on a questionnaire developed for similar purposes in a French study. The questionnaire was given to students at the beginning, during the middle period and towards the end of ICT-based lessons, to examine attitude changes over time. Apart from compiling simple statistics of responses the data was subjected to a form of statistical analysis which allows links to be made between questions.

Results

The contexts the teachers worked in, their personal and institutional histories

Interviews, school visits and teachers' journals enabled case studies to be constructed. An attempt to summarize these in the space available here is not possible. An overview of contextual factors, however, can be given. This is presented under five headings: competence and confidence; scheduling; assessment; school policy; hardware and software.

It was anticipated that teachers' ICT competences or mathematical expertise might be factors in the type of work they did with their classes. It was further anticipated that technical or mathematical 'problems' might arise and undermine their confidence. There was no clear evidence that either of these anticipated situations were realized. Teachers' perceptions of their ICT competences ranged from 'minimal' to very high. Further to this no clear pattern was observed between the teachers' highest mathematics qualification or their expressed view of the nature of mathematics and their use of ICT in lessons. An example may make this more meaningful. In one school the two teachers were at the extremes of the competent/confidence spectrum. They were planning work on mathematical functions with graphic calculators. The technical teacher wrote a complicated program. The less technical teacher utilized a simple idea. Both agreed that the simple idea was mathematically more interesting and demanding for their students. Regarding confidence there were many cases, reported and directly observed, of situations which presented mathematical or technical problems for the teachers. There were, however, no reported or observed 'crises of confidence' in these situations. The only reported crises of confidence arose from a teacher who felt that his class was concerned that the ICT work would not help them with their examinations.

Scheduling work involved getting started and continuing ICT work. Starting ICT work, the first lessons, was an important milestone for most of the teachers. Several teachers started straight away. Others found that they were double checking technical and pedagogic matters to ensure that these first lessons went smoothly. Once ICT work started all but one of the teachers arranged their ICT work in sequences of lessons using ICT and periods where no ICT work was done. The exception was a teacher who had made a weekly booking to use a computer suite. She claimed this required considerable 'juggling' of her scheme of work and that she would 'block' ICT work in the future.

There was no evidence that any teacher planned work that would lead to an understanding of mathematics or ICT other than that which might be assessed in an external examination. All but one teacher expressed concern at some stage about the possible negative effect of ICT work on their students' examination results[5] .Two teachers' project classes were Year 11 GCSE classes. Both severely curtailed their planned ICT work because, as this planned work approached, they were seriously concerned that this work would be a luxury which their examination classes could not afford. One of these teachers was clearly reacting to the exam concerns of her class. The other teacher expressed dismay, in the end of year interview, that the ICT work on graphs he had done was not examined in that year's GCSE papers. Two other teachers ensured that the spreadsheet work their classes had done was submitted for accreditation by a vocational awards institution.

[5] The project had an ethical principle that the ICT work must not jeopardise students' scholastic interests and that ICT work should be set aside if teachers felt that this might happen.

Whole-school ICT policies and practices varied greatly over the project schools. A simple description of two extremes were one school which prescribed that 'Mathematics will do spreadsheets' and another school where the Headteacher stated "ICT policy must arise from the body of the staff or it will not work". All schools were working towards incorporating ICT work into students' classroom experiences in departments rather than separate ICT lessons and recognized that staff development was an essential part of the ICT policy. There were instances where stated policy and actual practice were not compatible. The project did not model the relationship between school policy and teacher practice but did note specific features. Awareness of ICT policy is important. The two teachers who made the least use of ICT were not aware that their senior managers wanted them to experiment. The school which prescribed that 'Mathematics will do spreadsheets' generated resentment in the teachers who would have liked to be able to choose the ICT tools they used. Teachers in schools which unambiguously encouraged staff/departments to make their own decisions appeared to have fewer anxieties about their work. The nature of Ofsted report comments on school and department use of ICT certainly appeared to affect practices: negative comments appeared to generate specific and less flexible approaches to the use of ICT in lessons. The small number of schools involved and the subtle ways factors interrelate in a school, however, means that these statements must be regarded with caution.

Access to hardware and the type(s) of software used very clearly affected teachers' perception of the value of the ICT work they did with their classes. Six of the teachers had easy access to computers and stated that this gave them a flexibility in how and when to use them that they enjoyed. Five of the teachers had to compete for computer suite bookings and stated that advanced planning often constrained what they did.

Three of the teachers made use of algebraic or geometry packages which took them and their students some time to master. All stated some personal and student frustration with this. Two of the teachers made exclusive use of graphic calculators which their students could not take home. There was clearly an issue of students not becoming sufficiently expert in their use. Spreadsheets appeared fairly straightforward for all to master for the mathematical uses to which they were put. Graphic packages were quickly mastered and this aspect was praised by all who commented on their use.

Teachers' planning and use of resources

Interviews, observations and teachers' journals clearly indicate that using ICT involved considerable extra work for all the teachers. It typically involved familiarization with software, network training, time going through resources, syllabi and schemes of work and time to write and try out worksheets. In every case this extra work was biased towards the beginning of the project. In the early months of the project teachers spent one and two hours per week, on average, between on activities related to their project class.

All of the teachers made considerable use of a textbook. All but two of the teachers in the early months of the project felt that textbook work was inappropriate in ICT-based lessons. As the year went on three other teachers found that they were able to use the textbook for ICT-based work and another found that she could write worksheets based on textbook work.

Three tried using software specific published materials but did not make significant use of these, stating that the materials did not match with what they wanted to do. There appears to be a practical problem in the use of written resources for ICT-based lessons.

There was a common feature in the development of the teacher-produced worksheets in the early months of the project. Initial worksheets were invariably technology orientated in two ways: focusing on the technology itself (commands such as 'open', 'highlight', 'drag') and then focusing on how mathematics is done on the technology, e.g. how to input mathematical expressions or scale graphs. There is a sense in which this is quite a natural development: if you want to do mathematics on a computer package, you first have to learn how to use the package.

It would be misleading to give teachers the impression that teachers can accommodate ICT-based activities into their lessons without significant extra work.

Classroom practices

This section focuses on the SCAN analysis and comparative data collected in ICT and non-ICT lessons. For brevity only certain features are reported upon.

Comparing the 13 non-ICT lessons with the 38 ICT-based lessons nine features stand out as significantly different. The figures below represent averages.

	non-ICT	ICT
(1) the percentage of time spent in teacher-whole class exposition	48%	19%
(2) the percentage of time teachers spent talking to two or more students	28%	45%
(3) the percentage of time students spent listening to the teacher	45%	13%
(4) the percentage of time students worked in pairs or groups as opposed to on their own	figures are not reliable	
(5) the percentage of time teachers spent coaching or eliciting ideas from students	19%	4%
(6) the percentage of time teachers spent explaining or facilitating mathematical ideas	44%	29%
(7) the percentage of time teachers spent explaining or facilitating technological features	0%	24%
(8) the number of assertions teachers made during lessons	9	35
(9) the number of instructions (or initiating remarks) teachers made during lessons	15	50

NB The percentages were obtained from an analysis of 30 second intervals and should be taken as indicators rather than exact descriptors.

(1) and (3) are related since there was a high correlation between teacher exposition and students listening. All 13 video-taped non-ICT lessons were of the form 'teacher exposition followed by students working on exercises'. The significant reduction in teacher-exposition in ICT-based lessons may be viewed partially as an organizational factor in that six of the teachers prepared their classes before they moved to the computer room.

The percentage increase in (2) largely reflects the fact that the availability of computers forced students to work with two or more to a machine. It is interesting to note, however, that even

when students worked in pairs in non-ICT lessons the teacher talk was largely directed to one of the pair but in ICT-based lessons the teacher talk was largely directed to all students around a computer.

The figures for (4) are not reliable simply because the camera and the microphone were focused on the teacher, not the whole class. The significance comes from the conviction of the university-based researchers who observed lessons and analysed video-tapes. Pair work in non-ICT lessons was common but pairs tended to come together to discuss and then move to individual work. In ICT-based lessons the common screen focus appeared to generate more time working together.

(5) concerns 'coaching', the teacher pointing out mathematical features without revealing the answer. The significance of these figures lies in the relative absence of this in ICT-based lessons.

(8) and (9) represent the average number of assertions and instructions teachers made. These averages conceal great variation over teachers and different lessons. One reason for the greater average in ICT-based lessons was an apparent propensity in ICT-based lessons for six of the teachers to move quickly around the class ensuring that technical problems did not slow work down, "copy cell B3 to D3".

Pedagogic significance may be derived from comparative figures that were not numerically significant. For example, the questions teachers asked students during lessons were analysed with respect to their depth, e.g. requiring recall or extending ideas, and the level of guidance, e.g. highly structured or open. There was no evidence to support claims of deeper and more open questions in ICT-based lessons.

Overall the SCAN analysis does not indicate significant changes in teachers' roles in ICT-based lessons other than those that have quite straightforward explanations.

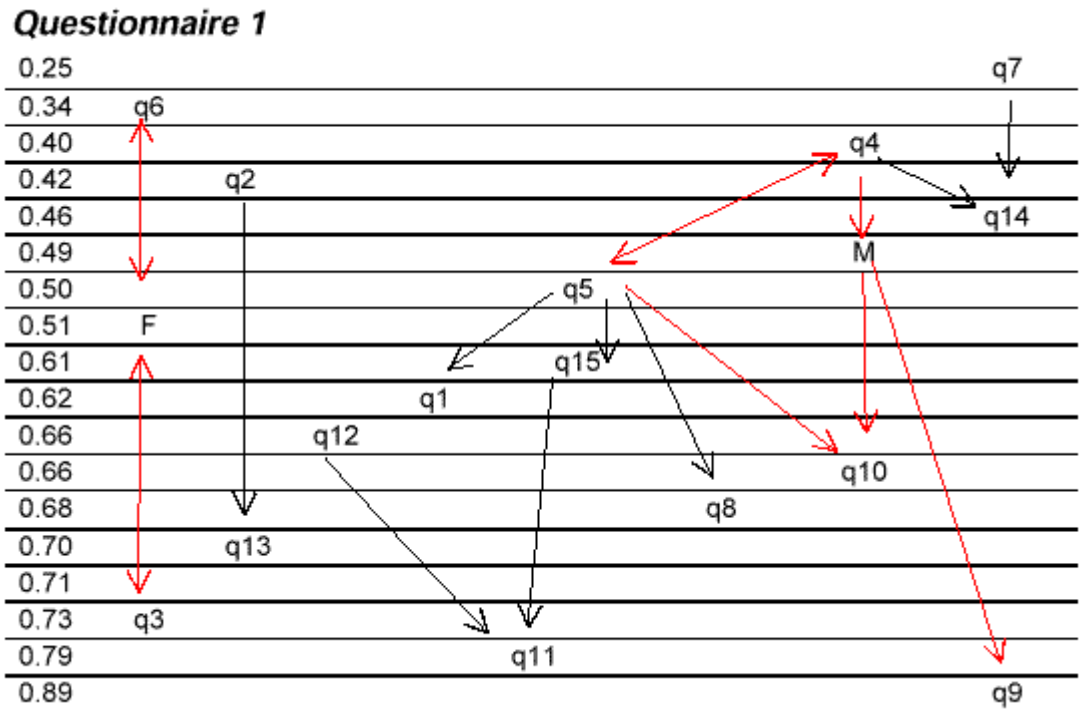
Student learning and attitudes

Teachers reported that they considered that the ICT-based work did not affect their students' assessed learning either positively or negatively. The difficulties over the design of tests to access student learning of specific mathematical topics covered in ICT-based lessons have been mentioned. Outcomes from these tests are thus not explored here.

An initial analysis of the attitude questionnaire data has been done but further work is required. A statistical analysis which allows links to be made between questions generated diagrams such as the one below, for questionnaire 1, for all three questionnaires. This requires some explanation. The numbers in the left column represent the mean responses over 293 students (weightings given to YES, yes, no, NO were, respectively, 1, $\frac{2}{3}, \frac{1}{3}, 0$). Lines with arrowheads, e.g. from question 2 to question 13 indicates that students who agreed with question 2 agreed with question 13 significantly more than the average student.

An initial analysis of this diagram suggest that girls have more negative attitudes towards using technology in mathematics lessons (technology does not help me in exams, technology is

complicated and provides little help) and a cluster of positive attitudes towards technology for students who respond positively to questions 4 and 5 (technology increases my desire to do/understand mathematics.



Space does not permit an exploration of links in questionnaires 2 and 3. It is worth noting that the links between girls and questions 3 and 6 remain and that the number of links increases significantly.

43 interviews with students were conducted after the questionnaires were returned. Students were selected for interview who either gave a typical or an atypical response with regard to the overall responses of there class. It is interesting to note that every student selected as an atypical respondee, bar one, may be said to have had a negative attitude to the use of ICT in mathematics lessons. Responses included "but I enjoy repetitive calculations" and "using technology advantages kids with wealthy parents".

Activities

Four of the teachers and the two university researchers gave a presentation of work at the 1999 annual conference of the Association of Teachers of Mathematics and the Mathematical Association. Three of the teachers and the award holder have led INSET courses based on project work. Two of the teachers will input into the day conference on 'Good Practice in the Use of ICT in Schools: Utilizing Teachers' Experience' to be held in London, March, 2000. The award holder has given presentations based on project work at the Universities of London (Institute of Education), Warwick and Liverpool John Moores as well as presenting a paper at the 12th International Conference on Technology in Collegiate Mathematics and leading a half day session to the 'Mathematics Educators in Northern Universities' group. Further presentations are expected.

Outputs

(1) A series of articles in three issues of the professional journal *Micromath* (volumes 14/3, 15/2 and 15/3, 1998/99). The majority of these articles are written by teachers. This collection of articles is included as one of the publications. The award holder was assured that this was acceptable by Dr Farnden of the ESRC and was told that a professional publication was permissible.

(2) Monaghan, J. (to appear) 'Practical Issues Arising when Teachers Move from Occasional to Regular Use of Technology'. *Proceedings of the 12th International Conference on Technology in Collegiate Mathematics*. Reading: Addison-Wesley.
This paper was restricted to five pages.

The award holder is currently working on five articles to be submitted to refereed academic journals. One article on classroom behaviours and another on attitudes. Three case studies co-authored by teachers: one an extended version of (2) above; one focusing on constraints a teacher experienced; one examining the sequencing of ICT-based work.

Six of the teachers and the award holder are in negotiations with Falmer Press about a book on getting started with ICT for mathematics teachers.

Impacts

As a result of the project two of the teachers have written materials for the Open University New Opportunities Funding (NOF) training programme and three of the teachers have written materials for the Leeds NOF consortium.

Future Research Priorities

Although the targetted data collection and analysis was completed to schedule the data generated by the project is rich in detail and further issues are likely to arise. The teacher-researcher dimension has not been examined in detail to date. Two aspects which will be examined in the near future are an evaluation of teacher-researcher pairs, as opposed to single teacher-researchers, in school-based projects and teacher-researchers' appropriation of project aims and objectives.

This project has a natural successor, a similar project monitoring whole mathematics department moves to incorporate ICT-based work into their teaching. There appears to be no study of this kind to date. Difficulties are bound to be experienced because, with very few exceptions, mathematics departments contain teachers who are extremely reluctant to incorporate ICT into their lessons. Finding solutions strategies to this problem is important for the uniform entitlement of students.