End of Award Report

Eliciting situated expertise in ICT-integrated mathematics and science teaching

Background
This research aimed to elicit the teaching expertise involved in productively integrating use of information and communication technologies (ICT) into classroom practices in secondary-school mathematics and science.

The research literature shows that experts have acquired intuitive specialist knowledge to meet the demands of everyday situations (Ericsson and Smith, 1991). Such 'knowledge in action' is interwoven with the social, physical and cultural context in which activity and learning take place (Brown et al., 1989). Thus, expertise is tuned to the setting and shaped by structuring resources available in the situation (Lave, 1988). Equally, expertise incorporates an important degree of flexibility and the capacity to respond to the uncertainty and contingency which are normal in real life situations (Wynne, 1991).

When digital educational technologies are introduced into school settings, mathematical and scientific knowledge are recontextualised and restructured (cf. Wynne, 1991). Likewise, pedagogic expertise is adapted to the constraints imposed and the benefits perceived (Wertsch, 1998). By examining practitioners' expertise across a range of classroom settings we have been able to analyse and understand how teachers adapt and reframe their actions and goals in appropriating the use of ICT. In addition, we have examined how teachers seek to respond to uncontrolled factors – such as unanticipated pupil responses and organisational constraints.

The naturalistic tradition of research underpinning the theoretical orientation of this study seeks to access the complex ‘craft knowledge’ of practitioners through eliciting teacher accounts and interpretations of their own pedagogic practices (Brown and McIntyre, 1993). Our approach to research involves ‘reverse engineering’ subject pedagogy (Ruthven, 2002) so that practitioners’ expertise can be elicited and codified, thus furthering the development of scholarly knowledge about teaching.

Such research is highly pertinent to current policy and practice. Judgements from school inspection reports regarding the development of ICT use in Mathematics have remained negative, concluding that “despite significant government funding, the use of ICT to promote learning remains a weak and underdeveloped aspect of provision” (Ofsted, 2004b, p.4). In Science, however, official judgements have become more positive over time, so that “the competence of science teachers to use ICT... in the classroom to promote pupils' learning is good or better in over four fifths of schools” (Ofsted, 2004a, p.4).

Given that “the best practice is excellent but it is not shared widely enough” (Ofsted, 2004a), our study aims to make a more strongly analytic contribution to such wider sharing, responding to the call for prioritising identification of pedagogic strategies and principles underlying successful practice (Becta, 2003; DfES, 2003), and addressing the need for “well informed, shared approaches to a few significant and effective applications in various areas of the curriculum, which are clearly documented to show why they are winners” (Ofsted, 1999).
Objectives

The study has been successful in its overarching aim of identifying, documenting and analysing several exemplary cases of a range of established teaching practices which integrate use of ICT in supporting the teaching and learning of mathematics and science, as follows.

Our approach to identifying exemplary cases was as follows. First, through seeking expert recommendations, and then cross-checking them, we identified (52) subject departments where exemplary practice might plausibly be found. Second, through conducting focus group interviews with members of (21) subject departments, and then examining the extent to which different forms of ICT use were endorsed, and in what terms, we selected (5) promising teaching practices for further investigation. Finally, through identifying which teachers had been particularly articulate about each chosen form of ICT use, we assembled a structured portfolio of (19) teacher-practice cases, considering also the potential for illuminating comparisons. At each stage, of course, the participation of departments and teachers depended on willingness and feasibility.

The five practices chosen for investigation were: use of (1) dynamic geometry, and (2) graph plotting, both in mathematics; and use of (3) multimedia simulation, (4) data capture and analysis, and (5) interactive whiteboard, all in science. Further detail on the portfolio of cases is provided in Annexe 4, and on the selection process in the Methods section and Annexes 1, 3.

Our approach to documenting cases involved observing two lessons for each teacher/practice case, and conducting post-lesson teacher and student interviews to elicit participants’ thinking about the lesson (as detailed under Methods). Through these interviews, the study has been successful in achieving its objectives of stimulating the teachers and the students involved in these exemplary cases to articulate, and reflect on, their models of how use of ICT is supporting teaching and learning.

Finally, our approach to analysing the cases of each practice, individually and collectively, was as follows. After initial familiarisation with the range of material related to a practice, teacher interview transcripts were analysed through a recursive process involving the development and refinement of a system of codes, aiming first to capture the ideas expressed about each particular lesson, and then to draw together related ideas across interviews by organising them thematically. Lesson observations and other material were used to amplify and refine analysis of some themes, particularly where it either illuminated or extended teachers’ accounts. The study has thereby been successful in achieving its objectives of eliciting, identifying and representing the situated expertise guiding teaching in these exemplary cases, and conducting cross-case, within-practice analyses aimed at identifying transposable components and situational variants in pedagogy. The two research products accompanying this report present such analyses.

Methods

In this section, we detail the processes of case identification and selection, and of data collection and analysis, with pointers to supporting Annexes.

In Phase 1, a process of multiple recommendation and reference (informed by academic colleagues, subject advisors, practitioners and school inspection reports) was used to identify subject departments regarded as relatively successful in terms both of the general quality of the subject education that they provide, and of the integration of ICT into their practice (see Annexe 1). Enquiries yielded far fewer unequivocal recommendations than anticipated, but eventually provided a suitable field of schools located within 125 miles of Cambridge.

In Phase 2, semi-structured focus group interviews were conducted within 11 mathematics and 10 science departments where three or four key users of ICT were invited to nominate and describe, from their experience, examples of successful ICT-supported subject practice (see schedule in Annexe 2). Through a process of review, which took into account the prevalence and commonalities of these examples, a smaller number of teaching practices
were selected for more intensive investigation (see Annexe 3). Priority was given to forms of ICT use which were widely reported as positively enhancing specific aspects of student learning; this led, for example, to a decision not to examine the use of spreadsheets in Mathematics, given that teachers primarily represented them as increasing the efficiency of classwork across a range of topics. Equally, priority was given to forms of ICT use seen to be in tune with the developing curriculum.

In Phase 3, teachers who had been particularly articulate in support of a selected practice were invited to help us to gain greater insight through participation in case studies during Phase 4. The aim was to work with several teachers engaged in the same practice, in different settings, varied by school, pupil group, and topic. Alterations to teaching schedules and other organisational factors precluded some willing teachers from taking part (see section 6), and eventually 11 science and 8 mathematics case studies (a minimum of three cases for each of the five practices) were undertaken across 11 schools (see Annexe 4). All of these schools had specialist status; six were designated as Leading Edge schools.

This process produced a range of sources of evidence about each practice. First, material relevant to each of the chosen practices was extracted from the transcripts of the departmental focus group interviews conducted in Phase 2. The main sources of evidence were gathered through two lesson observations and post-lesson interviews. Each observed lesson was audio-taped, and together with lesson materials, digital photographs, samples of students’ work, and researchers’ notes, an observation record of each lesson was compiled. Following each observed lesson, two semi-structured interviews were conducted, one with the teacher, and another with a group of six students (aged 11-16, selected by the teacher from across the academic range). Printed prompt cards were displayed and discussed in sequence (see Annexes 5 and 6). These prompts were intended both to provide participants with a focus for reflection and reference, and to standardise data collection within and across cases. In particular, the teacher interviews were designed to elicit their thinking about key actions in making the use of ICT successful; the student interviews elicited their thinking about how technology use and teacher action contributed to their learning. All observation and interview techniques were piloted in relation to each subject.

The main analysis of each practice (Phase 5) followed intensive preliminary reading of the available material. Analysis of the post-lesson teacher interview transcripts for that practice was then undertaken by importing them into a computerised database designed to assist the coding and retrieval of material (QSR*NUDIST and HyperResearch were employed). First, open coding of a teacher’s ideas about a particular lesson was carried out; this was followed by axial coding of similar material across lessons, through an iterative process of constant comparison (Glaser and Strauss, 1967), directed towards a thematic organisation of ideas (see sample coding scheme in Annexe 5). Observed teaching episodes, pupil perspectives and in particular, earlier departmental focus group data, were used to refine analysis of some themes, especially to illuminate or extend teachers’ accounts. Drawing on the analytic approach of Yin (1998), these within-practice, cross-case analyses aimed to identify transposable pedagogic principles as well as situationally specific ways of realising ideas shared by different practitioners engaged in similar practices.

The ethical guidelines of the British Educational Research Association (available at http://www.bera.ac.uk/guidelines.html) were adhered to throughout the project. Schools, teachers and pupils were offered anonymity and all potentially identifying information was removed from any data records which might be externally viewed or included in reports and presentations.

RESULTS

Mathematics

The rationales which teachers advanced for nominating many ICT tools emphasised their capacity to increase the ease, speed and accuracy with which routine mathematical tasks could be carried out, allowing attention to be focused on the key mathematical ideas at issue.
We chose graph plotting and dynamic geometry for closer investigation because the rationales offered for their use went further, highlighting the way in which the relative immediacy of feedback in the computer medium helped to create a more interactive sense of the relation between the modification of an equation and change in its graph, or the dragging of a figure and change in its measures.

Teachers saw both types of software as assisting them in adopting an investigative approach to key curriculum topics. Lessons were designed around carefully structured and controlled mathematical situations, intended to maintain focus on target properties. At some times the whole class was led by the teacher; at others, pupils worked, often in pairs, at their own machines, guided by printed worksheets and teacher interventions. While teachers reported that ICT (compared with pencil and paper) was particularly successful in making more active and investigative approaches viable with classes of lower ability, they structured lesson tasks to a greater degree for such classes, and were particularly concerned with the straightforwardness of software. An important factor contributing to this concern was the relative infrequency with which each software package was used; typically a few times a year per class, affecting the technical proficiency which pupils could be expected to develop and retain.

Teachers reported employing a range of strategies to introduce pupils to required techniques and help them recall them, including:

- step-by-step whole class demonstrations;
- step-by-step printed instructions, including screen images and/or keying sequences;
- coaching individuals/pairs, sometimes on new techniques in response to emergent needs;
- promoting free exploration of facilities by pupils, followed by plenary reporting and teacher moderation of new techniques. Equally, teachers were alert to the ways in which the availability of projection and printout facilities could contribute to effective communication and recording of examples.
Use of graph plotters in treating relations between equations and graphs

Archetypical practice involved using graph plotters to examine the relationships between equations and graphs, notably through exploring the effects of changing the coefficients of equations on their corresponding graphs. Most frequently mentioned were linear and quadratic graphs.

Teachers were sensitive to the part that attention to individual points played in underpinning the sense of a graph as a rule-governed set of coordinate pairs; this led them to draw pupils’ attention to the relationship between individual points and whole graphs when they judged such underpinning to be necessary. Equally, tasks were carefully structured so that pupils gained experience of modifying and varying the numerical coefficients of an equation before the use of literal parameters was introduced.

Graph plotters were seen as relatively readily usable by pupils. Teachers were alert to important variations in the features provided by different packages, and to how the availability and accessibility of such features could contribute to effective teaching, learning and problem solving:

- zooming and other rescaling operations to capture a graph in the graphing window;
- colour coding to highlight association between equation and graph;
- tabulation facilities and trace displays to establish a pointwise perspective on graphs;
- grid markings to highlight gradient as ratio of vertical to horizontal components;
- dynamic editor to structure the incrementing of coefficients treated as parameters;
- flexibility of permitted equation forms, to widen the range of graphs examinable, and minimise demands of symbolic manipulation.

In lessons where tasks were posed in relatively unconstrained terms (or where pupils breached the specified constraints), the examples chosen and the questions posed by pupils sometimes led teachers into mathematical argumentation which went beyond the controlled examples typical of work with pencil and paper (such as when pupils chose coefficients with very large or small magnitudes, or examined the equations defining implicit functions. Here, teachers’ sound understanding and effective exploitation of graph plotters (for example, to rescale and superimpose) sometimes played an important part. This evidences an important mediating influence of technology on mathematical-pedagogical activity.
Use of dynamic geometry in treating angle properties of shapes (see attached paper)

Archetypical practice involved using dynamic geometry to examine the angle properties of shapes, notably through dragging figures to generate multiple examples and detect invariant measures; topics frequently mentioned were vertically opposite, supplementary, corresponding and alternate angles; angle sums of the triangle and other polygons; and angle properties of the circle.

Dragging of figures was used to evidence properties in two ways. Most commonly, it was employed to examine multiple examples or special cases of a geometric figure, without attention to variation during dragging, other than in evoking the multiplicity of possibilities. Occasionally it was used to examine dynamic (non-)variation in a geometric figure during the dragging process. Regardless of the type of dragging employed, consideration of geometric properties was almost always mediated by the effects of dragging on numeric measures.

In lessons on one particular topic, the visual presentation and sequential organisation of material were particularly strongly shaped by adoption of a dynamic approach; in particular, teachers were observed to incorporate episodes into their lessons in which the distinctive 'dynamic' image on the screen was (tacitly) related to the more customary 'static' image which students would subsequently encounter when tackling exercises on the page.

In general, teachers saw dynamic geometry systems as relatively difficult for pupils to use for themselves. In departmental interviews, this was reported as a disincentive to use. In all the cases studied, teachers reported, for example, that pupils experienced difficulty in selecting elements within figures reliably; consequently, one teacher prioritised introducing pupils to techniques for simplifying figures through deleting spurious points and lines. Indeed, one teacher (working with lower ability classes) used only class demonstrations, while others limited direct pupil use largely to dragging prepared figures.

Where teachers did expect pupils to construct simple dynamic figures for themselves, an important motivation was the idea that pupils' thinking was shaped by the mathematically disciplined character of the software. Equally, while some teachers sought to protect their pupils from situations where the results produced by the software diverged from expectation (such as in measuring reflex angles, or in summing rounded measures), other teachers saw such incidents as providing opportunities for mathematisation, and for instilling a critical attitude to computer results.
Science

Teachers perceived the use of multimedia simulation, data logging and interactive whiteboards to offer a range of significant, technology-specific, advantages over alternative forms of practical work or textbook use in addressing key curriculum topics, as summarised separately below. Their rationales converged on one major theme where these technologies proved particularly powerful, namely that of exploiting interactivity and dynamic visualisation in rendering underlying scientific concepts and processes salient for learners. In each case the technology offered a manipulable object of joint reference for teachers and pupils (or peers).

As in mathematics, lessons were designed around examination of carefully structured and controlled situations, intended to focus attention on the phenomena of interest whilst guiding pupils in exploring the consequences of manipulating variables or interpreting results. The key pedagogical strategies emerging included:

- careful preparation, selection and adaptation of resources
- focusing – constraining the domain; accentuating key concepts and underlying relationships
- using real life examples; articulating and challenging everyday beliefs; discussing and reformulating shared experiences and linking them with scientific explanations
- building up and linking conceptual knowledge over a series of lessons; consolidation and application
- pre-empting perceived pitfalls of the technologies

Mode of use of each of the technologies varied across the cases and within lessons, incorporating: teacher-led demonstration, introduction, exposition and recap; individual/pair work by pupils at their own machines, guided by printed worksheets and teacher interventions; interactive whole class teaching, typically using question-and-answer and projected visual aids as stimuli.

Use of multimedia simulation to explore physical and biological processes (see attached paper)

The five cases studied employed simulations relating to three topics: terminal velocity, light mixing, and osmosis and diffusion. The ways in which participating teachers perceived this powerful tool to support science learning corroborated those previously reported (e.g. Baggott and Nichol, 1998; Osborne and Hennessy, 2003). Simulation offered opportunities for pupil exploration and experimentation, along with idealised, dynamic and visual representations of physical phenomena and experiments which would be dangerous, costly or otherwise not feasible in a school laboratory.

Technology use was integrated (and sequenced) in various ways with complementary practical work, theory exposition and plenary discussion. Different teachers also structured activity and supported learning in diverse ways, as exemplified through two contrasting case studies involving a ‘terminal velocity’ simulation. One teacher engaged in whole class interactive teaching, employing the projected simulation as a visual stimulus for pupil questioning and reasoning and hence as a tool to support ‘dialogic’ communication (Mortimer and Scott, 2003). He mediated its use through collaborative testing of pupils’ hypotheses, attending to everyday beliefs, and reconciling these with observed outcomes and scientific explanations. In another case, pairs of pupils manipulated the software but were confined by tightly structured tasks. The teacher valued ‘learning by doing’ but in practice articulated the science underlying the observed motion rather than building on or supporting testing of pupils’ own ideas. Such worksheet-driven lessons were typical across our sample and presented little opportunity for pupil reasoning. Over-structuring of tasks plus pressure to ‘cover’ an overloaded curriculum meant that the rhetoric of ‘discovery learning’ in the simulations literature, and teachers’ own aspirations to balance student experimentation with use of structured tasks, were not borne out. The constraints on teachers can obstruct them in
providing effective guidance and timely intervention to multiple pupils working in ‘hands on’
mode. We concluded that pedagogic expertise for using multimedia technology effectively can
be adapted to situational constraints via interactive whole class teaching which supports
scientific knowledge building through engaging pupils in collaborative investigation,
articulation and critical scrutiny of persistent everyday conceptions.

**Use of technology for data capture and analysis**

Recording and handling experimental data through use of sensing equipment is part of the
statutory science curriculum but despite widespread acknowledgement of its potential benefits
in supporting pupil investigations inside and outside the classroom, demonstration remains
the common mode of use (Finlayson and Rogers, 2003).

Use of data logging was teacher-led in all of our four case studies and involved pupils in
two types of activity: a) interpreting cooling curves during studies of energy or earth materials
and b) interpreting and emulating distance-time graphs in lessons on motion. Teachers
viewed the technology as enabling pupil attention to be focused on science through alleviating
laborious data collection and graph production; they aimed to harness it to support
development of pupils’ observational and analytical skills and, in the motion activity, to
facilitate learning through kinaesthetic engagement. Dynamic graph display was perceived as
aiding conceptualisation by providing a tangible representation of abstract concepts, and
immediate feedback enabled actions to be monitored and adjusted. Teachers had developed
efficient practical routines in which data logging approaches were used alongside other
practical and written work to offer additional perspectives and reinforce understanding, though
the balance of lesson activities was configured and managed to suit particular groups, for
example through providing different levels of pace, challenge and explication.

Enabling interaction with data whilst the activity is current rather than after the event (as is
often the case when lesson time is spent in manual graph production), was seen as
motivational for pupils and beneficial to their learning; teachers typically used the projected
display to stimulate whole-class discussion of results. Real-time plotting supported use of
prediction to capture pupils’ interest and focus on outcomes. Such prediction was also
regarded as helpful in guarding against pupils’ tendency to overly rely on the trustworthiness
of computer-generated data by encouraging them to scrutinise output and question
anomalous results. It was considered important that pupils should understand how logged
data is being generated and teachers used a variety of techniques including metaphor and
practical example to show how data collection and display related to the entity being
investigated. Familiarisation, rehearsal and contingency planning were regarded as key to
successful use of the technology.

**Use of the interactive whiteboard to support whole class teaching**

Interactive whiteboards (IWBs) have more than tripled in number in secondary schools during
the course of this 2-year project. Research is in its infancy but IWB use is believed to improve
teacher-pupil interaction through promoting effective questioning (DfES, 2004). *Pupil
manipulation* potentially offers opportunities for collective scientific knowledge building.
However, recent work with primary teachers (Kennewell, 2004) found that their use was
reinforcing a teacher-centred pedagogy. Our four case studies investigated use in these
areas: terminal velocity; horizontal projection and collisions; Newton’s third law of motion and
gaseous exchange at the alveoli; food webs and ecology fieldwork preparation.

Our forthcoming paper details situational variation while some common cross-case themes
emerging are outlined here. *Banks of teaching resources* related to each curriculum topic are
being built up, drawing on everyday examples plus presentations, animations and video clips
painstakingly selected from Internet, CD-ROM and other sources. IWB software significantly
facilitates organisation and presentation of resources and instantaneous transition between
them. Continual access to the whiteboard proved essential for building up competence and confidence: teachers had begun to move beyond a presentation/demonstration (‘blackboard’) mode towards more discerning and purposeful use which exploits interactivity, provisionality and annotation. This shift resulted in whiteboard dependence whereby IWB use had become fully integrated (‘an organic part of my teaching process’) and unavailability provoked insecurity.

Teachers and pupils unanimously agreed that active pupil manipulation of objects on the IWB was beneficial – in terms of motivation, involvement in constructing graphical representations and a related increase in understanding. A comfortable atmosphere was engendered to foster collaboration and overcome pupil reticence, albeit with only partial success. However limited opportunity for physical participation by learners was actually observed in most lessons and little evidence of planning for this or of attending to pupils’ own ideas emerged. Teachers asserted that IWB use for whole class teaching generated more opportunities than ‘blackboard’ teaching for interaction with pupils during interspersed individual/group work; pupils valued such teacher assistance, although these interludes did not allow learners to exploit features of the IWB. Realising the potential of ICT is generally a slow, evolutionary process (Hennessy et al., 2005; Kerr, 1991); existing pedagogical approaches and thinking appear to be shaping IWB use, whereby previous lesson plans are ‘tweaked’ to incorporate a broader range of more exciting, interactive multimedia content. The IWB significantly enhances rather than transforms classroom practice, particularly lesson preparation, although teachers recognised the scope for further exploitation of its unique features.

Conclusion

Our observations of worksheet-driven simulation use and teacher-led data logging activity whereby expected relationships are simply verified, coupled with theory teaching via teacher-controlled use of the interactive whiteboard, collectively indicated that ICT use is being shaped by the established culture of school science, where little genuine ‘investigation’ takes place and the pedagogic emphasis is on covering the syllabus in preparation for examination (Donnelly, 2000). Teachers reported that curriculum time constraints obstructed pupil use of data logging equipment due to set-up time needed, ‘playing’ with simulated variables, and desired extension of IWB work. These findings reflect a systemic subject culture which is, initially at least, subsuming new interactive technologies by using them mainly for demonstration. However some practitioners employed interactive whole class teaching methods in eliciting, testing and challenging pupils’ own conceptions, and building scientific knowledge through discussion and synthesis.

Concluding remarks

We have characterised a range of exemplary teaching practices which integrate use of (rapidly changing) ICT in supporting the teaching and learning of mathematics and science. Some general principles have emerged, along with some ways in which teachers configure technology activities to fit their own settings. The tools we studied were designed to support particular pedagogies, and the literature likewise assumes that these offer opportunities for pupil manipulation, experimentation, discovery and reasoning. While teachers endorse such use in principle, it is not always realised in practice owing to situational adaptation – to different pedagogical approaches, curriculum time limitations, pupil groups, resources available and physical features of the technology and setting. Thus we can characterise ‘expert practice’ only in light of currently operating contextual constraints. Some practitioners have made major strides in structuring use of the technologies so as to represent and develop target concepts effectively for particular learners. Implications of the findings for design of technology-integrated activity are discussed in our papers in each domain.
Activities
During the course of the award, members of the research team have kept in contact with researchers and practitioners in the field through contributing to a wide range of meetings organised by national agencies, notably the British Educational Communications and Technology Agency (Becta), and the Qualifications and Curriculum Authority (QCA); and by participating in the annual meetings of the British, European and American Educational Research Associations.

Results of one analysis (of archetypical use of dynamic geometry in mathematics) were presented at the 2004 meeting of the British Educational Research Association. Further presentations of findings relating to all mathematics and science practices are scheduled for seven conferences during 2005 (see Annexe 8 for details).

Outputs
The full list in Annexe 8 indicates that publications are being prepared for both academic and professional audiences. For example, in relation to the first analysis to be completed (dynamic geometry in mathematics), two publications are in preparation for leading research journals, and two articles (one reporting the analysis of archetypical practice; the other making suggestions for developing it) have been already been accepted by the professional journal Micromath. Further articles are planned for appropriate journals of the other professional associations in the United Kingdom and United States. Publications following this broad pattern are in preparation for each of the other four practices.

The attached article on simulation has been submitted to the International Journal of Science Education and another paper on data logging aimed at practitioners will be submitted to School Science Review. An accessible review of classroom uses of ICT to support science teaching and learning was commissioned and published by Nesta Futurelab. A research review is being prepared for Studies in Science Education.

Selected reports will be disseminated via the Becta ICT Research Network. All publications will also be downloadable from our website (http://www.educ.cam.ac.uk/istl/pub.html).

Impacts
Outputs from the project are being circulated to appropriate academic and professional contacts. For example, the analysis of archetypical use of dynamic geometry was sent to members of the current working group of the QCA on Mathematics and ICT, which includes representatives from the professional associations in mathematics education, the mathematics inspectorate, the National Strategies, and the DfES (ICT in Schools division). It has become an influential point of reference for discussion of future plans for curriculum and assessment policy and pedagogical guidance.

Future research priorities
We intend to complete a full publication programme from this project, and, although not part of this proposal, to carry out further within- and cross-practice analysis. The project has yielded a rich dataset which can be exploited in several ways in future.

We also intend to synthesize our findings with those of other projects; notably Interactive Education (Sutherland, 2004) in which the focus has been on design initiatives aimed at developing practice, complementing our studies of practice currently regarded as exemplary.

We have already obtained ESRC funding for a new 30-month project on teacher mediation of subject learning with ICT, commencing in January 2005 (RES-000-23-0825). This builds on SET-IT through again involving ‘expert’ practitioners, this time as co-investigators. It employs
digital video with the aim of producing DVDs for wide dissemination of replicable exemplars of successful practice, thus increasing the impact of SET-IT findings.

The findings have indicated a number of ways in which current professional practice could be strengthened; future work—in collaboration with practitioners and relevant national agencies—is envisaged to develop and disseminate enhanced approaches. Developing an appropriate synthesis of methods of design experimentation, lesson study and didactical engineering to support such development and dissemination will provide the basis of a future proposal to the ESRC.

References


Annexe 1: Procedure for selecting schools during Phase 1

Initial nominations of exemplary practice were sought from colleagues in University Faculties of Education, Ofsted, subject organisations, and subject advisors and inspectors from eight local education authorities. They were asked to recommend examples of particularly successful classroom use of computer-based tools or resources integrated within the teaching and learning of mathematics and/or science at any level of secondary education (preferably in schools located within 2 hours driving distance of Cambridge). In addition, departments needed to have adequate access to ICT facilities (assuming that this would be the case in most schools by – or soon after – the end of the project so that results could be generalisable to typical schools). It was notable that most of our ‘expert practitioners’ had access to some form of projection (or other) technology in their own teaching room.

Responses were somewhat more diffident than had been anticipated; some sources appeared reluctant to designate ‘successful’ practice – for example where there was uncertainty about the extent to which a promising practice might, or might not, have been sustained by an individual. Assurances that recommendations would be cross-checked against all available information were helpful here. We did not expect to receive nominations based upon quantifiable learning gains generated by a particular approach. Rather, we were looking for examples of ICT tools and resources being utilised appropriately (not necessarily innovatively) by skilful practitioners to enhance subject teaching and learning in ways that might be replicable – whilst recognising that any given ‘expert’ practice would be subject to the curricular and organisational constraints upon the setting. Pursuing additional sources of recommendation meant that eventually an annotated database of 62 nominated departments in 52 schools was compiled.

School prospectuses and websites were scrutinised for indicative school characteristics such as current specialist status. The most recent Ofsted school inspection report was reviewed in each case, with particular attention to comments regarding effective classroom use of ICT within the department/s concerned. Priority for selection was given to individuals/departments commended by more than one source and corroborated by Ofsted reports – and where reports were out of date or inconclusive, to those recommended by at least two other sources.

Identified individuals were contacted and each invited to recruit three departmental colleagues to participate in a focus group interview to discuss a small number of examples of the types of classroom practice with ICT which, from experience, they considered to be especially successful – and why. Some selected departments were ultimately unable to participate as explained in section 7. We had originally aimed for 10 departments in each subject and focus group interviews finally took place in 21 departments (11 mathematics and 10 science) across 18 schools.
Annexe 2: Protocol for conduct of focus group interviews

All participants were sent a briefing sheet prior to the interview; groups were encouraged to identify and agree suitable examples beforehand and, where appropriate, to supply supporting material such as on-screen demonstrations and worksheets. Interviews lasted approximately one hour and were audio-recorded. Researchers also requested a brief tour of each school, focusing on ICT use and provision. Data arising from these visits included interview transcripts and materials, researchers’ visit notes and proformas summarising participant information.

Interview Procedure

1. Researcher explained the procedure and gave assurances regarding anonymity of participants.
2. The group was asked to describe briefly the 2 or 3 examples chosen.
3. Discussion focused on each activity in turn, with a view to building a deeper understanding of how ICT is used to support it.

Further prompts concentrated on eliciting the following information:

Working circumstances
- pupils: year; ability; grouping?
- where carried out (e.g. classroom/computer suite)?
- description of activity/task
  - used in relation to which topic area(s)?
  - how it fits with other activities in the lesson
  - towards what outcome(s); products?
  - collaboration?
- what ICT resources used: software; networks; peripherals
- role of other resources within the lesson(s)?

Indicators of success
- in what way(s) successful?
  - same for all ability groups?
- how such success was identifiable?

Features underpinning success
- what factors or processes are key to this success?
- how/why they make a difference?

Specific contribution of ICT
- what was the specific role of using ICT in enhancing learning (further to those already mentioned)?
- how is this different from the same (or similar) activities not using ICT (or possibly using other forms of ICT)?

Specific contribution of teacher
- what key actions are undertaken by the teacher to support learning activities (including preparation) and help achieve success (kinds of support / degrees of direction)?
- how/why they make a difference?

Incorporation into departmental scheme of work
For each example, how well-established it is within the department as a whole, in terms of:
- use by teachers across department; how many teachers / groups
- progression through year groups / follow up
- what time(s) of year; any flexibility?
- available resources / access
Annexe 3: Protocol for selection of practices for further investigation

A systematic review of examples presented during focus group interviews was conducted according to the criteria shown below, drawing on interview records. Material was evaluated independently by the three members of the project team in order to provide triangulation. One key consideration was the inclusion of practitioners who exhibited well-developed and articulated pedagogical thinking about integrating technology use.

Criteria for selection:

Practices - Essential
(a) Each is said by teachers to offer advantages above conventional means and to contribute positively to pupil learning;
(b) Each is widespread enough to give some scope for within-practice cross-case comparison and analysis;
(c) Collectively they provide further scope for cross-practice analysis (varied in terms of content and teaching approach);
(d) Classroom applications only (not computerised administration/assessment systems)

Practices - Desirable
(e) Examples exploit the technology more fully (eg whole class interactive teaching, modelling and discussion with pupil input, using touch-screen and annotation features of IWBs – rather than didactic uses and simple teacher-controlled projection of images);

Teachers - Essential
(a) No insurmountable practical obstacles (willingness to participate; reliable access; convenient timing of target teaching episodes);
(b) motivation, confidence and skills for using ICT systematically, effectively, appropriately;

Teachers - Desirable
(c) pairs of practitioners engaged in similar practices;
(d) well-developed, integrated practice, sustained over time (but not stagnant)
(e) level of pedagogical thinking is sophisticated and reflective
(f) strategies articulated for structuring and supporting learning
(g) comfortable with new ways of working; high expectations of students;

Two promising practices (dynamic geometry and graph plotting activities) emerged in mathematics and three (multimedia simulations, datalogging and interactive whiteboards) in science.

The logistical difficulties encountered in securing subsequent participation of individual teachers and arranging the relevant observation sessions are documented within Sections 6 and 7 of this report. The final portfolio included a range of practices, varied by teacher, pupil age group, topic and mode of use, permitting scope for some within-practice comparisons (See Annexe 4). Ultimately 19 case studies of individual teachers were undertaken (8 mathematics and 11 science) involving five practices across 12 schools.
Annexe 4: Design of Case Study Portfolios

Mathematics Cases
For both graph plotting and dynamic geometry, a decision was made to study several cases of what the departmental interviews had identified as archetypical forms of practice. In dynamic geometry, two further promising ‘outlier’ cases were also included; one (F/N) because it appeared to correspond more closely (than what emerged as the archetype) to the type of practice envisaged by software pioneers; the other (P/V), because it appeared to be an innovative adaption of the software to meet the particular concerns of practitioners. In graph plotting, there were no promising, distinctive outliers of this type.

The availability of suitable lessons and the feasibility of accessing them proved a constraint, but eight mathematics cases (three graph plotting, five dynamic geometry) were documented across five schools. In total, 16 observations with post-lesson interviews were conducted. Normally, each case involved two lesson observations in which the teacher was observed teaching similar topics to different classes. The pattern of observations achieved provided some scope for comparison of the archetypical forms of practice across participating teachers and student groups.

**GRAPH PLOTTING**

<table>
<thead>
<tr>
<th>School / specialist status¹</th>
<th>Teacher</th>
<th>Topic 1</th>
<th>Year/ability group</th>
<th>Topic 2</th>
<th>Year/ability group</th>
<th>Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>B TC</td>
<td>T</td>
<td>Linear graphs</td>
<td>8 middle</td>
<td>Quadratic graphs</td>
<td>10 higher</td>
<td>Omnigraph on interactive whiteboard, and on student desktop computers</td>
</tr>
<tr>
<td>E SC</td>
<td>H</td>
<td>Linear graphs</td>
<td>10 lower</td>
<td>Reciprocal and quadratic graphs</td>
<td>9 higher</td>
<td>Autograph projected onto ordinary whiteboard, and on student desktop computers</td>
</tr>
<tr>
<td>N TC; B</td>
<td>M</td>
<td>Linear graphs and simultaneous equations</td>
<td>10 higher</td>
<td>Function transformations</td>
<td>10 higher</td>
<td>Omnigraph on interactive whiteboard; student use of graphic calculators</td>
</tr>
</tbody>
</table>

**DYNAMIC GEOMETRY**

<table>
<thead>
<tr>
<th>School / specialist status</th>
<th>Teacher</th>
<th>Topic 1</th>
<th>Year/ability group</th>
<th>Topic 2</th>
<th>Year/ability group</th>
<th>Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>F LE; MC</td>
<td>N</td>
<td>Triangle perpendicular bisectors [two consecutive lessons]</td>
<td>7 higher</td>
<td>Golden rectangle and ratio</td>
<td>10 higher</td>
<td>Geometer’s SketchPad on ordinary whiteboard from tablet computer, and on student desktop computers</td>
</tr>
</tbody>
</table>

¹ Key to abbreviations for specialist school status: B = Beacon; LE = Leading Edge School; MC = Maths and Computing College; SC = Sports College; TC = Technology College.
<table>
<thead>
<tr>
<th>TC; B</th>
<th>F</th>
<th>Polygon angle sums</th>
<th>9 lower</th>
<th>Circle theorems</th>
<th>10 lower</th>
<th>CabriGeometry on ordinary whiteboard from laptop computer</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>L</td>
<td>Circle theorems</td>
<td>9 higher</td>
<td>[only one lesson available]</td>
<td></td>
<td>CabriGeometry on interactive whiteboard, and on student desktop computers</td>
</tr>
<tr>
<td>P</td>
<td>V</td>
<td>Triangle trigonometry [two non-consecutive lessons]</td>
<td>11 middle</td>
<td>[two lessons same from series]</td>
<td></td>
<td>CabriGeometry on interactive whiteboard, and on student laptop computers</td>
</tr>
<tr>
<td>P</td>
<td>W</td>
<td>Polygon angle sums</td>
<td>7 higher</td>
<td>Corresponding angles</td>
<td>8 higher</td>
<td>CabriGeometry on interactive whiteboard, and on student laptop computers</td>
</tr>
</tbody>
</table>
Science Cases
There were 11 Science case studies (four datalogging, four multimedia simulation and three interactive whiteboard; see note below), across eight schools. Each case comprised two lesson observations and interviews, i.e. 22 in total.

Our aim was for the year group to remain constant within each practice, but the constraints outlined earlier in section 6 precluded this. In most cases, lessons involved two different classes from the same year group. Where possible, for simulations and datalogging, the topic remained constant across the two observations. (The exception was teacher J whom we observed using datalogging in lessons on two different topics). For interactive whiteboards, the teacher remained constant across topics, which varied.

Multimedia Science School² software was used by all of the case study teachers who employed simulations in their lessons. Many science departments had obtained these tools through their participation in NOF (New Opportunities Fund) training programmes run by the Science Consortium.

Note: One of the teachers (G)* used both an interactive whiteboard and a simulation; another (K)** employed both datalogging and simulations in his lessons; in these cases, relevant data were included in the analyses of both practices.

MULTIMEDIA SIMULATIONS

<table>
<thead>
<tr>
<th>School / specialis status</th>
<th>Teacher</th>
<th>Topic (constant across lessons)</th>
<th>Year/ability group Lesson 1</th>
<th>Year/ability group Lesson 2</th>
<th>Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>W LE; B</td>
<td>G*</td>
<td>Terminal velocity</td>
<td>11 mixed</td>
<td>11 mixed</td>
<td>Lesson 1: Simulation on interactive whiteboard Lesson 2: Simulation on student desktop computers</td>
</tr>
<tr>
<td>D LA</td>
<td>K**</td>
<td>Terminal velocity</td>
<td>9 upper</td>
<td>9 higher</td>
<td>Simulation projected onto ordinary whiteboard</td>
</tr>
<tr>
<td>J LE; SC</td>
<td>A</td>
<td>Light/colour mixing</td>
<td>8 upper</td>
<td>8 middle</td>
<td>Simulation on student laptop computers</td>
</tr>
<tr>
<td>J LE; SC</td>
<td>R</td>
<td>Osmosis</td>
<td>10 higher</td>
<td>10 middle</td>
<td>Simulation projected onto ordinary whiteboard</td>
</tr>
<tr>
<td>D LS</td>
<td>C</td>
<td>Osmosis</td>
<td>10 lower</td>
<td>10 higher</td>
<td>Simulation on student desktop computers</td>
</tr>
</tbody>
</table>

DATALOGGING

<table>
<thead>
<tr>
<th>School / specialis status</th>
<th>Teacher</th>
<th>Topic (constant across lessons)</th>
<th>Year/ability group Lesson 1</th>
<th>Year/ability group Lesson 2</th>
<th>Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>G LE; TC</td>
<td>D</td>
<td>Cooling curves (earth materials)</td>
<td>10 middle</td>
<td>10 higher</td>
<td>Temperature probes linked to laptop computer; projected onto ordinary whiteboard</td>
</tr>
<tr>
<td>G LE; TC</td>
<td>E</td>
<td>Cooling curves (radiation)</td>
<td>10 higher</td>
<td>10 middle</td>
<td>Lesson 1: Temperature probes linked to laptop computer Lesson 2: As above, projected onto wall</td>
</tr>
<tr>
<td>K LE; SC</td>
<td>J</td>
<td>Cooling curves (radiation)</td>
<td>n/a</td>
<td>10 middle</td>
<td>Temperature probes linked to laptop computer</td>
</tr>
</tbody>
</table>

² Multimedia Science School Software on CD-ROM (New Media Press Ltd). Website: http://www.new-media.co.uk
<table>
<thead>
<tr>
<th>School / specialist status</th>
<th>Teacher</th>
<th>Topic 1</th>
<th>Year/ability group</th>
<th>Projected resources</th>
<th>Topic 2</th>
<th>Year/ability group</th>
<th>Projected resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>N TC; B</td>
<td>O</td>
<td>Horizontal projection</td>
<td>10 higher</td>
<td>Intranet links to resources including animations and movie clips; Powerpoint presentation</td>
<td>Collisions</td>
<td>10 (same group as Obs 1)</td>
<td>Internet-derived quiz; Powerpoint presentation; video and movie clips</td>
</tr>
<tr>
<td>P LE; MA</td>
<td>U</td>
<td>Food chains</td>
<td>9 middle (doing Yr 10 work)</td>
<td>ActivStudio flipcharts including manipulable food chains</td>
<td>Ecology (fieldwork planning)</td>
<td>9 (same group as Obs 1)</td>
<td>ActivStudio flipcharts including photos, definitions, planning task</td>
</tr>
<tr>
<td>S LE; TC</td>
<td>B</td>
<td>Motion</td>
<td>10 middle</td>
<td>‘Notebook’ of electronic slides including photos &amp; diagrams</td>
<td>Gaseous exchange</td>
<td>10 middle</td>
<td>‘Notebook’ of electronic slides including animation, photo &amp; textbook diagrams</td>
</tr>
<tr>
<td>W LE; B</td>
<td>G*</td>
<td>Terminal velocity</td>
<td>11 mixed</td>
<td>MSS simulation</td>
<td>Terminal velocity</td>
<td>11 mixed</td>
<td>Powerpoint presentation including diagrams</td>
</tr>
</tbody>
</table>

Key to abbreviations for specialist school status:

- B Beacon
- LC Language College
- LE Leading Edge School
- MA Media Arts College
- MC Maths and Computing College
- SC Sports College
- TC Technology College
Annexe 5: Example of prompts used during post-lesson teacher interviews

Prompts 1-5 were generic across practices and used in both post-lesson interviews for each case. Additional prompts 6a and 7a (specific for each practice) were included in the first interview, and replaced by prompts 6b and 7b in the second:

Graph plotting in mathematics

1. **Your thoughts while preparing the lesson**
   - What you wanted the pupils to learn
   - How you expected use of the technology to help pupil learning

2. **Your thoughts looking back on the lesson**
   - How well pupils learned what you wanted.
   - How well the technology helped pupil learning

3. **Further thoughts looking back over the whole lesson**
   *At each stage of the lesson, the important things that you were giving attention to, picking up on, and doing*

4. **Your thoughts about successful learning of mathematics in the lesson**
   *One or two examples of successful learning of maths by pupils where use of the technology was involved*
   - What you did (or had already done) to help make that learning successful

5. **Your thoughts about key actions in making use of the technology successful**
   - The key things that you did in preparing for the lesson to make use of the technology successful
   - The key things that you did during the lesson itself to make use of the technology successful

6a. **Your thoughts about suggested pitfalls of computer/calculator graphing**
   - Pupils may accept what they see on the screen too readily, without interpreting it mathematically.
   - Pupils may not understand the relation between a graph, its equation, and the coordinates of its points.
   - Pupils may superimpose too many graphs, confusing which is related to which defining equation.
   - Pupils may not appreciate how the appearance of a graph is affected by the scaling of the axes.

7a. **Further thoughts about pitfalls of computer/calculator graphing**
   - The main pitfalls you have experienced
   - Ways you have found of avoiding or managing these pitfalls

6b. **Your thoughts about differing approaches**
   - How you may have modified this type of lesson using graphing technology in the light of your experience of using it
   *Whether you have taught this kind of lesson using a different kind of graphing technology If so, how this lesson would have been different*

7b. **Your thoughts on any ways in which the approach differed between the two lessons**
Any differences of approach related to the topics covered in the two classes
Any differences of approach related to the time or place of the two lessons
Any other differences of approach
Annexe 6: Prompts used during post-lesson pupil interviews

Prompts were printed on large cards for ease of viewing by the whole group; the researcher displayed the cards in sequence. These prompts were used across practices.

1. **Your thoughts on what was good about the lesson**  
The main things that were good  
What made them good

2a. **Your thoughts on what you learned about the topic**  
The main things that you learned  
What helped you to learn them

2b. **What your teacher did to help you learn**

3. **Your thoughts on what was difficult in the lesson**  
The main things that were difficult  
What made them difficult

4. **Your thoughts on using ICT in the lesson**  
The main ways it helped or not  
What it was that made them helpful or not

5. **Your thoughts on what could have been better about the lesson**  
The main things that could have been better  
What difference they would have made
Annexe 7: Sample Coding Scheme (Science Simulation Cases)

This scheme was initially developed through iterative scrutiny of the multimedia simulations case study interview data and focus group material pertaining to simulations, and used to code this body of data in Hyper-Research. It was subsequently adapted for the two other science practices, to include new coding arising from recursive examination of the interactive whiteboard and datalogging interview data respectively.

1.0 ADVANCED PLANNING STRATEGIES

1.01 familiarisation (with technology and its limitations)
1.02 backup plans

2.0 LEARNING AIMS / SUCCESS

3.0 REAL TIME STRATEGIES

Real time strategies for facilitating learning
focusing (includes structuring to highlight/prioritise concepts)
idealisation (e.g. constraining no. of variables, rigging expts)
avoid distraction
differentiation
challenge (‘stretching’ pupils)
adaptation (of colleague’s ideas/resources to own context)
flexibility (contingency action e.g. targeting areas of weakness/ adjusting to P differences / responding to technical problems)
discussion (includes talking through answers, reflecting, interpreting, evaluating; with or without ICT, teacher with individuals or class)
prompting (to make links)
questioning (e.g. description of what’s happening; other prompting)
plenary (Q&A)

explanation
mediating between pupils and ICT (teacher input needed: related to mode)
teacher-pupil interaction
interpending terms
coaching individuals (e.g. praising)
pupil pacing (includes chivving)

lesson pacing or sequencing
demonstrating ICT features
demonstrating practical
building up concepts / building on previous work
balance (structure or curriculum delivery vs experimentation)

4.0 ROLE OF ICT (positive affordances: expectations, realisation)

4.01 feasible (assumes comparison with no ICT)
4.02 visualisation / model
4.031 memorable (link to visualisation)
4.04 time saving
4.05 hands-on (experience / interactive)
4.06 immediate feedback
4.07 own pace
4.08 dynamic

5.0 PITFALLS

5.01 listed

5.011 literal interpretation
5.012 superficial interaction
5.013 trialling constrained

5.02 other

5.03 strategies (to pre-empt/counter)

6.0 LESSON CONTRASTS (general code yields background info)

6.01 no ICT (includes contrast with practical work)
6.02 scheduling (e.g. time of day)
6.03 other

7.0 EVOLUTION Evolution of pedagogic strategies over time (including between 2 lessons)

- **rationale** (strategic role)
- **customisation** (of commercial worksheets; selection of questions / simulation slides etc.)
- **assessment** (formal or informal, in lesson or planned)
- **feedback from pupils** (about learning)
- **experimentation** ('playing', prediction, pupil manipulation & control; includes hands-on and practical investigation as well as ICT)
- **collaboration** (includes pupil comments on group work)
- **potential** (ideally)
- **unsuccessful strategy**
- **modification** planned or desirable with hindsight or if time allowed
- **revision consolidation** (includes recap / pulling together / reinforcement)
- **countering misconceptions**
- **ability** (individual or group – differences in pupil outcomes or ICT success; advance or real time differentiation strategies)
- **behaviour** (individual or group dynamic)
- **learning styles**
- **ICT skills** / literacy / experience and response to them; teacher or pupil
- **other pupil characteristics** (e.g. language/literacy; gender differences)
- **teacher ‘philosophy’** (characteristic approach)
- **discerning use**
- **practical investigation** / demo (complementary role or alternative)
- **follow-up plans**
- **records** (printouts, notes, resource sheets etc)
- **self access** (pupils access technology in own time)
- **technical issues**
- **technical help**
- **motivation** (& teacher’s response)
- **management** (classroom organisation; includes getting/maintaining pupils’ attention, monitoring – pupils on task)
- **mode of use** (interactive/demo/wholeclass/individual machines)
- **other technology animations**
- **background** (contextual information)
- **constraints** (external e.g. curriculum pressure, national policy; time)
- **self-regulation**
- **homework**
50.0  SCHOOLS

50.01  School W
50.02  School J
50.03  School D

60.0  TYPE

60.01  Teacher
60.02  Pupil
60.03  FG
60.04  Obs

70.0  PRACTICE

70.01  IWBs
70.02  simulations
70.03  datalogging
Annexe 8: List of SET-IT publications and presentations

Hennessy, S., Deaney, R. & Ruthven, K.
**Situated Expertise in Integrating Use of Multimedia Simulation Into Secondary Science Teaching.**
Submitted to the *International Journal of Science Education.* (copy attached)

Ruthven, K., Hennessy, S. & Deaney, R.
**Incorporating dynamic geometry systems into secondary mathematics education: didactical perspectives and strategies of teachers.**
Paper presented at Symposium on Developing Teacher Thinking about Integrating ICT Use in Mathematics Classroom Practice, at the *Annual Conference of the British Educational Research Association (BERA)*, Manchester, September 2004. (copy attached)
Revised and extended version to be submitted shortly to *Educational Studies in Mathematics.*

Ruthven, K., Hennessy, S. & Deaney, R.
**Current practice in using dynamic geometry to teach about angle properties.**
Micromath, 2005, in press.

Ruthven, K.
**Expanding current practice in using dynamic geometry to teach about angle properties.**
Micromath, 2005, in press.

Osborne, J. and Hennessy, S.
**Science Education and the Role of ICT: Promise, Problems and Future Directions.**

Publications and presentations in preparation and planned:

Articles reporting the case studies of interactive whiteboard use, data logging and graph plotting are presently in preparation, as well as a further paper treating the outlier cases of dynamic geometry. Analyses and papers which compare data across practices and subjects are also planned, and some of our conference presentations next year will include these.

Hennessy, S., Deaney, R. & Ruthven, K.
**Developing pedagogical expertise for integrating use of the interactive whiteboard in secondary science.** In preparation for *British Educational Research Journal* and to be presented at *Annual Conference of the Association for IT in Teacher Education (ITTE)*, Dundee, July 2005.

Deaney, R., Hennessy, S. & Ruthven, K.
**Teachers’ strategies for making effective use of data logging in secondary science lessons.**
In preparation for *School Science Review* and planned to be presented at *Association of Science Education,* January 2006.

Hennessy, S., Deaney, R. & Ruthven, K.
**Situated expertise in technology-integrated science teaching: mediating learning and adjusting to constraints.** Paper to be presented at symposium on Pedagogical Approaches for Technology-Integrated Science Teaching (convenor: S. Hennessy) at the Computers and Learning conference (CAL-05), Bristol, April 2005. Other symposium contributors are the Open University and the Bristol TLRP InterActive Education science team. Paper subsequently to be submitted to *Computers & Education.*

A review of the research on science teaching and learning with ICT is being prepared by Hennessy for the journal *Studies in Science Education.*
Ruthven, K., Hennessy, S. & Deaney, R.

Incorporating dynamic geometry into secondary mathematics: teacher perspectives and practice.

Ruthven, K., Hennessy, S., & Deaney, R.

Teacher constructions of dynamic geometry in English secondary mathematics education.
Paper to be presented at symposium on Constructions of Dynamic Geometry: The Socio-Cultural Shaping of Technology Use in Education (convenor: K. Ruthven) at the Computers and Learning conference (CAL-05), Bristol, April 2005. Other symposium contributors are Southampton University and the Bristol TLRP InterActive Education mathematics team. Paper subsequently to be submitted to Computers & Education.

Ruthven, K.

Hennessy, S., Ruthven, K. & Deaney, R.

Situated pedagogic expertise in technology-integrated mathematics and science teaching.

Note that all publications will be downloadable as WORD or .pdf files from our website at http://www.educ.cam.ac.uk/istl/pub.html.