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individuals/departments commended by more than one source and corroborated by Ofsted reports – and where reports were out of date or inconclusive, to those recommended by at least two other sources.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 (eg 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

School / specialist status[1]	Teacher	Topic1	Year/ability group	Topic 2	Year/ability group	Technology
B TC	T	Linear graphs	8 middle	Quadratic graphs	10 higher	Omnigraph on interactive whiteboard, and on student desktop computers
E SC	H	Linear graphs	10 lower	Reciprocal and quadratic graphs	9 higher	Autograph projected onto ordinary whiteboard, and on student desktop computers
N TC; B	M	Linear graphs and simultaneous equations	10 higher	Function transformations	10 higher	Omnigraph on interactive whiteboard; student use of graphic calculators

DYNAMIC GEOMETRY

School / specialist status	Teacher	Topic 1	Year/ability group	Topic 2	Year/ability group	Technology
F LE; MC	N	Triangle perpen-dicular bisectors [two consecutive lessons]	7 higher	Golden rectangle and ratio	10 higher	Geometer's SketchPad on ordinary whiteboard from tablet computer, and on student desktop computers
N TC; B	F	Polygon angle sums	9 lower	Circle theorems	10 lower	CabriGeometry on ordinary whiteboard from laptop computer
N TC; B	L	Circle theorems	9 higher	[only one lesson available]		CabriGeometry on interactive whiteboard, and on student desktop computers
P LE; MA	V	Triangle trigonometry [two non-cons-ecutive lessons]	11 middle	[two lessons from same series]		CabriGeometry on interactive whiteboard, and on student laptop computers
P LE; MA	W	Polygon angle sums	7 higher	Corresponding angles	8 higher	CabriGeometry on interactive whiteboard, and on student laptop computers

[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.

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 School[2] 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

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

DATALOGGING

School / specialist status	Teacher	Topic (constant across lessons)	Year/ability group Lesson 1	Year/ability group Lesson 2	Technology
G LE; TC	D	Cooling curves (earth materials)	10 middle	10 higher	Temperature probes linked to laptop computer; projected onto ordinary whiteboard
G LE; TC	E	Cooling curves (radiation)	10 higher	10 middle	Lesson 1: Temperature probes linked to laptop computer Lesson 2: As above, projected onto wall
K LE; SC	J	Cooling curves (radiation)	n/a	10 middle	Temperature probes linked to laptop computer
K LE ; SC	J	Motion	10 lower	n/a	Motion sensor linked to laptop computer, projected onto ordinary whiteboard
D LA	K**	Motion	9 upper	9 higher	Motion sensor linked to graphical calculator displayed via OHP onto ordinary whiteboard

[2] Multimedia Science School Software on CD-ROM (New Media Press Ltd). Website: http://www.new-media.co.uk

INTERACTIVE WHITEBOARDS

School / specialist status	Teacher	Topic 1	Year/ability group	Projected resources	Topic 2	Year/ability group	Projected resources
N TC; B	O	Horizontal projection	10 higher	Intranet links to resources including animations and movie clips; Powerpoint presentation	Collisions	10 (same group as Obs 1)	Internet-derived quiz; Powerpoint presentation; video and movie clips
P LE; MA	U	Food chains	9 middle (doing Yr 10 work)	ActivStudio flipcharts including manipulable food chains	Ecology (fieldwork planning)	9 (same group as Obs 1)	ActivStudio flipcharts including photos, definitions, planning task
S LE; TC	B	Motion	10 middle	'Notebook' of electronic slides including photos & diagrams	Gaseous exchange	10 middle	'Notebook' of electronic slides including animation, photo & textbook diagrams
W LE; B	G*	Terminal velocity	11 mixed	MSS simulation	Terminal velocity	11 mixed	Powerpoint presentation including diagrams

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
How this type of lesson would be different if you could not use technology at all
Whether and how this type of work with technology relates to other work on this topic

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
interpreting terms
coaching individuals *(e.g. praising)*
pupil pacing *(includes chivvying)*
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
4.021 memorable *(link to visualisation)*
4.03 features accentuated
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.
Nesta FutureLab report no. 6. http://www.nestafuturelab.org/papers.htm. September 2003.

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 adapting 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. Paper to be presented at the 6th *British Congress on Mathematics Education (BCME-6)*, Coventry, March 2004. Paper to be published in conference proceedings.

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.
Keynote address at *7th International Conference on Technology in Mathematics Teaching (ICTMT-7),* on the conference theme of **Visions of Mathematics Education: Embedding Technology in Learning**. Bristol, July 2005. Subsequent paper to be submitted to *Journal for Research in Mathematics Education.*

Hennessy, S., Ruthven, K. & Deaney, R.
Situated pedagogic expertise in technology-integrated mathematics and science teaching. Paper to be presented at *European Association for Research on Learning and Instruction Biennial Conference,* Nicosia, August 2005. Also to be presented at *British Educational Research Association Annual Conference,* Glamorgan, September 2005. Paper subsequently to be submitted to journal *Learning & Instruction*.

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.