

An investigation of the research evidence relating to ICT pedagogy

A report to the DfES by:

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Executive Summary

1 Introduction

This research project was commissioned by the British Educational Communications and Technology Agency (Becta) on behalf of the Department for Education and Skills (DfES) to investigate the effects of ICT pedagogy on attainment, based on evidence from the published research literature and a small set of cases studies in schools identified for their advanced and or integrated uses of ICT. This report is published in conjunction with a similar document which focuses on the available literature relating to the effects of ICT on attainment (Cox and Abbott, 2004). The two reports complement each other and serve to provide a good base in understanding the literature on ICT attainment and pedagogy.

The aims of the study were to conduct:

- a review of the existing literature on ICT pedagogy to identify aspects of the way in which ICT is used and the actions of teachers that can help to ensure that ICT will have some chance of having an impact on attainment
- a small-scale study of schools known to be using ICT effectively to support attainment, to gather additional data and to illuminate the findings emerging from the study of the literature.

Through the literature review and small case studies we aimed to address the following questions relevant to this study:

- 1 What are teachers' pedagogies?
- 2 What is the relationship between different types of ICT use and teachers' pedagogical practices?
- 3 What types of ICT hardware, software and communications are being used by teachers and for what purposes?
- 4 In what ways has IT been integrated with other more traditional teaching methods?
- 5 What are the levels of use of different types of ICT in schools?
- 6 What impact has ICT had on specific concept knowledge, on specific skills and on specific processes, and how does this relate to different teaching practices?

The literature review procedure involved:

- developing a framework of criteria, based on existing evidence, for deciding which literature should be used
- identifying a common set of keywords relevant to ICT uses across the different types of published evidence
- identifying the range and priorities of journals and other published sources to be reviewed
- conducting a review of research and statistical findings on issues relating to ICT and attainment
- identifying the gaps in current knowledge about ICT in education.

The study involved collecting data from over 350 published documents and from short cases studies of teachers in a range of primary and secondary schools.

There were 26 teachers in the case studies from six primary and seven secondary schools. The selection criteria were based on evidence of improved learning outcomes of their pupils through one or more of the following:

- Increased gains in subject tests compared with comparable classes.
- Improvements in class work demonstrated by comparing with other classes in the school.
- Quality of pupils' work compared with previous classes' achievements.

2 Evidence of the effects of ICT and pedagogy on attainment

The evidence from the literature and the case studies showed a range of teachers' pedagogies and pedagogical reasoning which influenced their uses of ICT and thereby the pupils' attainment.

Teachers' subject knowledge

The types of uses of ICT and the way it is used in lessons is influenced by teachers' knowledge about their own subject and how ICT relates to this. There is a clear division between the teachers who choose ICT resources to fit within a particular topic and those who choose it to present the pupils' work in an innovative way, without any direct application to the topic. The evidence shows that when teachers use their knowledge of both the subject and the way pupils understand the subject, their use of ICT has a more direct effect on pupils' attainment. The use of ICT has a more consistent effect on attainment when pupils are challenged to think and question their own understanding, albeit through using topic-focused ICT software on their own, in pairs or through a whole-class presentation. The effects of using ICT to present and discuss pupils' work are less well researched and therefore the effects on pupils' attainment are not so clear.

Access to ICT resources

An important influence on the eventual use of ICT in subjects and classes is the amount and range of ICT resources available to the teachers. Limited numbers of computers in a class, mostly in primary schools, was shown to have a restricting effect in some cases because each pupil was only able to use the computer for a few minutes. Whole-class use of an electronic whiteboard had both positive and negative effects. It promoted pupils' debates and helped them visualise difficult concepts and processes. However, some teachers focused only on the presentation aspects, disregarding the use of simulations and modelling which might have been more challenging for the pupils. Only a few teachers reported using subject-specific software which linked directly to the content and purpose of the curriculum. This ICT resource selection process affects the way in which teachers use ICT in lessons.

Teachers' pedagogical knowledge

The teacher's own pedagogical beliefs and values play an important part in shaping technology-mediated learning opportunities. Whether this results in technology being used as a servant to reinforce existing teaching approaches, or as a partner or extension of self to change the way teachers and students interact with each other and with the tasks is not yet clear from the research literature. Different types of ICT use require the teacher to have an extensive knowledge of ICT and to be able to fit its use either into their existing pedagogy or to extend their pedagogical knowledge so they can accommodate ICT effectively in their teaching.

Teachers' knowledge of the potential of ICT in education

In spite of teachers often being limited by the ICT resources available to them, there are many examples in the literature of teachers having a good understanding of a particular resource. However very few teachers have a comprehensive knowledge of the wide range of ICT resources now available in education. This means that their pupils are not given all the learning opportunities which ICT could provide.

Confidence in using ICT

Teachers are confident in their uses of ICT so long as they have chosen those uses. Few teachers are confident in using a wide range of ICT resources, and limited confidence affects the way the lesson is conducted. Many teachers still fear the technology, which prevents them making much use of ICT in their teaching.

Pedagogical practices of the teacher using ICT

The pedagogical practices of the teachers using ICT varied. Some made only small enhancements to their practices when using more traditional methods, while others made fundamental changes in their philosophy of teaching. These changes were in the way they taught their subject and the tasks required of the pupils. Some teachers replaced the blackboard and chalk with an interactive whiteboard on which to display content and ideas for class discussions in a traditional way, whereas other teachers enabled pupils to act out and film drama presentations and interviews and then build storyboards around these, ending with pupils' presentations using the whiteboard to the whole class.

These results show that the most effective uses of ICT are those in which the teacher and the software can challenge pupils' understanding and thinking, either through whole-class discussions using the whiteboard or through individual or paired work on a computer. If the teacher has the

skills to organise and stimulate the ICT-based activity, then either approach can be equally effective. This is elaborated in the following sections.

Organisation

ICT use has a limited impact on learning and teaching when teachers fail to appreciate that interactivity requires a new approach to pedagogy, and requires rethinking about how they plan their lessons and their whole curriculum. Some teachers radically reorganise the delivery of their curriculum, but the majority use ICT to add to or enhance their existing practices. One of the constraints to effective use of ICT is teachers' limited appreciation of the way their teaching needs to be rethought if ICT is to be an integral part of their pedagogical practices. Teachers need to employ proactive and responsive strategies in order to support, guide and facilitate appropriate learning activities.

Collaborative work and insights into pupils' learning

Using ICT with pupils in pairs, groups or with a whole class through, for example, the use of an interactive whiteboard, enables the teachers to gather more extensive feedback from the pupils by listening to their explanations. For example, one teacher reported that the pupils who hardly ever spoke were motivated to discuss the work with their colleagues, and hence the teacher was able to learn much more about what such pupils really understood.

Collecting a series of printouts of work at regular intervals helped to make the pupils' thinking visible to one teacher and enabled her to identify errors of understanding among the pupils as they progressed through the learning activity. Computer-based modelling has enabled teachers to gain deeper insights into pupils' understanding and progress in learning than they are able to obtain through other forms of pupils' expression.

Pedagogy beyond the classroom

A major part of teachers' pedagogies is in the planning, preparation and follow-up of lessons. This means that although many teachers are reporting that when using ICT they become a facilitator in the lesson instead of a leader, they still have a mainly leadership role in their overall teaching because they have planned and monitored the direction of the learning. In studies that have shown that little planning has occurred, the pupils' class work was unfocused and led to less than satisfactory outcomes. There is therefore a fundamental misunderstanding by many teachers and even teacher-trainers about how to incorporate ICT in their whole teaching programme.

3 Effects of pedagogical practices on pupils' attainment

There is extensive evidence of ICT contributing to pupils' attainment. However, all the evidence presented in this report shows that these benefits are dependent upon the way in which the teacher selects and organises the ICT resources and how the teacher integrates this use into other activities in the class and beyond.

What is clear from this study is that apart from a few exceptions, at present the uses of ICT are nearly always focused on specific aspects of the curriculum through the types of resources available. There are two clear areas where teachers have been shown to embed ICT in their teaching, and where this has enhanced learning:

- Science and mathematics, through the use of simulations, modelling and other specific ICT resources.
- English and literacy, through the use of word processing, multimedia presentation and interactive video.

4 Effective pedagogical practices for ICT

In this study we have identified a range of pedagogical practices which should be part of a teacher's pedagogical framework if they are going to be able to integrate ICT effectively into the curriculum and into teaching and learning.

- Teachers need to understand the relationship between a range of ICT resources and the concepts, processes and skills in their subject.

- Teachers need to use their subject expertise to obtain and select appropriate ICT resources which will help them meet the learning objectives of a particular lesson. Resources include subject-specific software as well as more generic resources.
- Teachers need knowledge of the potential of ICT resources, not only in terms of their contribution to pupils' presentation skills but in terms of their facilities for challenging pupils' thinking and extending pupils' learning in a subject.
- Teachers need confidence in using a range of ICT resources, which can only be achieved through frequent practice with more than one or two uses of ICT.
- Teachers need to understand that some uses of ICT will change the nature and representations of knowledge and the way the subject is presented to and engages the pupils.
- Teachers need expertise in organising pupils when using ICT resources within the class – understanding when pupils should work on their own, how working in pairs and groups should be organised and when to use ICT for whole-class teaching.
- Teachers need to know how to prepare and plan lessons where ICT is used so that lessons challenge pupils' understanding and promote reflection and thinking.
- Teachers need to know which kinds of class organisation will be most effective for the learning tasks, eg individual/pair/group work or a whole-class presentation.

There is still a large gap in knowledge and/or confidence, even among even many of the innovative teachers, with regards to the potential that a whole range of other ICT uses may have for their pupils' learning. This implies that the majority of teachers need further substantial support for their professional development regarding the use of ICT in their teaching in order to integrate ICT and improve pupils' attainment.

Main Report

1 Background

This study was commissioned by the British Educational Communications and Technology Agency (Becta) on behalf of the Department for Education and Skills (DfES) as part of the ICT and Attainment project, to investigate the effects of ICT pedagogy on attainment, based on evidence from the published research literature and a small set of cases studies in schools identified for their advanced and or integrated uses of ICT. This report is published in conjunction with a similar document which focuses on the available literature relating to the effects of ICT on attainment (Cox and Abbott, 2004). The two reports complement each other and serve to provide a good base in understanding the literature on ICT attainment and pedagogy.

Both studies were carried out by the same research team, and many of the procedures and methods used by the team were the same for both studies. A common feature of the two studies is the methodology for the review of the published research literature. The aim of this particular study was to investigate the most reliable and relevant published data to provide evidence of teachers' pedagogical practices with regard to ICT.

In addition, a small set of cases studies was carried out in schools identified for their advanced and or integrated uses of ICT. These illuminative case studies, identified by the literature review, of innovative teachers using aspects of ICT provided some useful insights into current practices among primary and secondary school teachers, and many of these would be worth following up over a much longer period. A common feature of these studies was the teachers' use of specific aspects of ICT. Indeed, there were no examples to be found of teachers using many aspects of ICT together, such as modelling alongside data handling or measurement and control. However, the teachers had integrated their specific uses of ICT into their everyday practice, which our reviews have shown is still not commonly done across schools in general.

An important limitation of the research reported here is the four-month time-scale of the projects. It is usual in any larger research project to conduct a literature review alongside empirical research and to include evidence from foreign as well as English language literature. It was not possible within the four months to review all the published evidence we know exists, much of which we have reviewed in previous studies. In order to utilise the evidence from this broader literature we have produced two literature bases. The first is a list of references to which the report specifically refers; these include a wide range of empirical findings and theoretical perspectives. The second is a bibliography which has informed and underpinned our approach and analysis. Much of the latter also describes specific examples relating to ICT and attainment and ICT pedagogy which could be examined in more detail in a later study. Because of their large size, these two literature bases are published separately to this report.

Ideally a literature review compares findings from a number of different studies, which were perhaps conducted several years apart, or with different ages of pupils or in different educational settings. Although we did not have sufficient time to be able to do this with all the publications, the evidence we have compared provides very useful findings and has implications for further research. It also raises questions about the effectiveness of different research methods. One of the main messages arising from the two studies is the need for a larger and longer-term literature review which would be able to draw out relationships between specific uses of ICT and the effects on attainment within a range of contexts.

2 Aims of the study

The aims of this study were to conduct:

- a review of the existing literature on ICT pedagogy to identify aspects of the way in which ICT is used and the actions of teachers that can help to ensure that ICT will have some chance of having an impact on attainment
- a small-scale study of schools known to be using ICT effectively to support attainment, to gather additional data and to illuminate the findings emerging from the study of the literature.

Through the literature review and small case study we aimed to address the following questions relevant to this study:

1. What are teachers' pedagogies?
2. What is the relationship between different types of ICT use and teachers' pedagogical practices?
3. What types of ICT hardware, software and communications are being used by teachers and for what purposes?
4. In what ways has ICT been integrated with other more traditional teaching methods?
5. What are the levels of use of ICT in schools for different types of ICT?
6. What impact has ICT had on specific concept knowledge, on specific skills and on specific processes, and how does this relate to different teaching practices?

3 Methodology

Various categories of data were extracted from the literature included in the review in order to achieve all the aims described above. This process also provided a framework for future literature reviews. One of the objectives of the review process was to develop some common understandings about ICT and pedagogy that will underpin future research projects into the use of ICT in education. The literature review process involved:

- developing a framework of criteria, based on existing evidence, for deciding which literature should be used
- identifying a common set of keywords to be used across the different types of published evidence
- identifying the range and priorities of journals and other published sources to be reviewed
- conducting a review of research and statistical findings on issues relating to ICT and pedagogy
- identifying the gaps in current knowledge about ICT in education.

The study involved collecting data, including quantitative surveys and statistical publications, qualitative or case-study data and previously published meta-analyses, from various sources. The emphasis was on identifying work that was both original and nationally important, and which addressed relevant issues. Additional attention was also given to the level of accuracy of the available literature and reported results, the variables considered and the applicability of results. Most of the information has been derived from well established and reputable paper-based and electronic information sources (see Section 3.5), but other internet searches were also used.

It should be noted that this literature review did not include a statistical meta-analysis because of the limited time-scales and resources. The methodology is explained in the following sections.

3.1 Literature search procedures

The first stage of the study involved establishing procedures for the literature search to ensure a systematic and relevant approach. This was especially important given the short time-scales of the project. The following strategies were agreed:

- Combining existing literature reviews and creating a framework for the evaluation.
- Deciding the criteria for the selection of the literature sources (i.e. the journals chosen and other web-based sources and official reports).
- Identifying and prioritising the range of journals to be reviewed and identifying the relevant reviewer for each journal, matched according to expertise.
- Developing a set of keywords, which would form the basis for the framework, enable the project to achieve consistency across reviewers, and allow keyword searches for analysis.
- Identifying the gaps in current knowledge about ICT in education.

3.2 Combining existing literature reviews and creating a framework for the evaluation

As a starting point, members of the review team contributed relevant articles from their existing literature reviews in ICT and education, which were used to develop an agreed framework. The framework was continually modified as additional evidence was analysed. To contribute to this framework and the review procedure, the team identified important categories for review (see Section 3.4).

Each of the publications included in the review was analysed and assigned keywords relating to the particular factors associated with ICT and pedagogy which they focused on. The full list of keywords used can be found in Appendix 1.

The publications included in the review were also categorised and given keywords according to the curriculum subjects they focused on (eg geography, science, literacy). Whenever possible, synthesis studies were used to winnow out the particularly relevant studies from the aggregate set of literature.

A number of ICT solutions were considered by the team for the recording and storing of the data extracted from the included publications. The final decision was to use EndNote because this would ensure consistency across the reviews for the different sources, and because it could then be easily used with any published document produced from the project. See Section 4.4 for further details.

3.3 Deciding the criteria for the selection of the literature sources

The criteria which were agreed for selecting the literature sources were the following:

- Sources would be searched from documents, web materials etc mostly published from 1990 to the present day. This was to enable us to include some of the important large-scale studies conducted during the early 1990s.
- Only English language literature would be used because of the limited duration of the project.
- Journals and articles would be prioritised according to their coverage of research in ICT and education, their relevance to Key Stages 1–4 (learners aged 4–16 years) and their coverage of relevant theoretical and empirical areas.
- Web-based sources would be searched according to the keywords we had established and the refereeing system for web publication which had been used (ie only academic papers published on the web which had had peer reviews would be included, but not personal publications by individuals with no obvious review method).
- Research reports on work conducted in the UK would be reviewed before reports of work in other countries.

3.4 Identifying and prioritising the range of journals to be reviewed

Using the set of keywords that emerged from our previous literature review and our existing literature databases, we identified a list of academic journals to be reviewed according to the priorities explained below. The full list of journals is given in Appendix 2, with Appendix 3 showing those prioritised to be reviewed first. In using these keywords we therefore reviewed literature which was directly relevant to Key Stages 1–4 in the UK, ie primary and secondary education and special needs education. We also reviewed other academic publications where possible, where the theory or empirical evidence was relevant but which might be, for example, focused on a tertiary study or informal learning at home. The ways in which the evidence was collated and categorised are detailed in Appendix 4.

3.5 Literature review data sources

The types of sources which we have used, as explained briefly above in Section 3.4, include the following:

Paper-based resources:

- Academic journals listed in Appendix 2.
- Research reports.
- Books.
- Monographs.

- PhD theses.

E-based resources:

- Research reports.
- Educational Technology Abstracts.
- Sociology of Education Abstracts.
- Sociological Abstracts bibliographic database.
- ERIC and zetoc, which provide access to the British Library's Electronic Table of Contents database of over 15 million article titles derived from the 20,000 most important research journals in the world, dating back to 1993. It is updated daily with approximately 10,000 new additions.
- Academic journal papers published online.
- Conference proceedings.

3.6 Small study in schools

The second part of the study consists of illuminating studies of teachers who are already known to be using ICT effectively to support attainment. In view of the short time-scales for the project, we adopted the methods explained in the following sections.

3.6.1 Selecting the sample

Twenty-six teachers were selected from a range of schools. We decided to select teachers rather than schools because we had previously found very large variations in teaching practices within single schools. The teachers who have participated in these case studies have either been already identified by the ImpaCT2¹ team or have been engaged in the DfES Best Practice Research Fellowship scheme.

The final selection of teachers and schools was based on the following criteria. The selection criteria were based on evidence of improved learning outcomes of their pupils through one or more of the following:

- Increased gains in subject tests compared with comparable classes.
- Improvements in class work compared with other classes in the school.
- Quality of pupils' work compared with previous classes' achievements.

We conducted studies with six primary and seven secondary schools. No special schools that were approached were able to receive a researcher during the very short period available.

3.6.2 Document collection

Through document gathering and observations of lessons, data were collected on teachers' pedagogical practices in relation to:

- the selection of the ICT resources
- the organisation of the ICT resources
- the planning of the lesson
- the organisation of the lesson, including lesson structure and pupil grouping
- teachers' perceptions of the value of the ICT activity
- the relationship between the ICT activity and the rest of the teaching activities
- teacher interventions
- follow-up activities.

¹ ImpaCT2 was a major study carried out between 1999 and 2002 involving 60 schools in England. It was one of the most comprehensive investigations into the impact of ICT on educational attainment so far conducted in the UK. It was commissioned by Becta on behalf of the DfES. (Comber *et al.*, 2002, Harrison *et al.*, 2002; Somekh *et al.*, 2002).

The documents also included examples of pupils' work, pupils' results in achieving specific tasks, web pages of work produced by pupils, and other work produced for specific projects in schools.

3.6.3 Observations of lessons

Observations of lessons given by the teachers who were interviewed were made where possible during visits to schools. The main reason for observing lessons was to assist researchers in understanding the comments that teachers made in interviews. The observations provided data related to research questions 2, 3, 4, 5 and 6 (see Section 2, p.7) and collected data on:

- individual pupil's uses of ICT
- pupil-computer interactions
- interactions between pupils
- tasks completed by the pupils
- teachers' input into the activity.

Researchers made notes of observations and completed an observation pro forma (see Appendix 5).

3.6.4 Teacher interviews

Teachers were interviewed to collect evidence to address questions 1, 2, 3 and 4 (see Section 2, p.7) on:

- teachers' perceptions of the value of the ICT activities they employ
- teachers' ideas, values and beliefs in relation to their practice
- the knowledge that teachers use to make pedagogical decisions.

The procedure and pro formas for these semi-structured interviews are included in Appendix 5. The interview was designed to encourage teachers to reflect on their practices and to help them to examine the decisions they make during the pedagogical reasoning process, the values and knowledge used, and the reasoning behind decisions that are made.

Prior to the interview, the teachers were sent an information sheet asking them to think about their pedagogies. They were asked to think about a particular lesson which they had taught where they felt that the use of ICT was effective and crucial in enabling pupils to learn, and which contributed to the improvement in pupils' attainment. Teachers were told that we wanted to understand the thinking that went in to planning and teaching that lesson, and the knowledge and beliefs that led to their decisions, and that we were particularly interested in:

- the learning objectives for the lesson
- the nature of the activities and the uses of ICT and associated resources
- the purpose and role of ICT in helping to achieve the learning objectives for the lesson
- the role of the pupils in helping each other to achieve the learning objectives for the lesson
- their role as the teachers and their interactions with the role of ICT
- their understanding of the pupils' knowledge, skills and abilities (including their ICT capability), which led to their planning decisions
- what the pupils learned in the lesson and the evidence for their learning
- how their teaching of this topic was different using ICT than when taught without the ICT facilities.

The aim was to move from specific examples to a more general and holistic understanding of their pedagogies, and they were told that in more general terms we would like to understand:

- how their teaching had changed with the use of ICT
- what they believed about the value and purpose of ICT in learning and teaching
- what evidence they had that ICT improves attainment and learning.

Teachers were advised that we needed to collect from them a summary of this evidence and supporting documentation which might include teachers' records of pupils' assessments, GCSE, SAT and end-of-year exam results, and pupils' self-assessments.

During the interview the teachers were prompted only where necessary, and the researcher used the checklist to ensure that key points had been covered. The intention, within the short time

available (maximum 45 minutes) was to focus on those aspects of the teachers' pedagogies in relation to ICT use that the teachers felt were most significant, and to understand their thinking through specific examples of ICT use.

3.6.5 Teachers' questionnaire

Questionnaires (see Appendix 8) were sent out to teachers prior to the interviews by post and email. The intention was to obtain factual information and teachers' views on some aspects of ICT use that would be used to build up profiles of teachers. The questionnaires enabled information to be obtained in a systematic way, and saved time during the interview.

The questionnaires were based on earlier questionnaires used in the Teachers as Innovators project (Preston *et al.*, 2000) and a questionnaire currently being developed by a PhD student (Nancy Castillo) who is measuring the levels of use and integration of ICT by teachers in Chilean schools. It was modified to fit the purpose of this study and address the issues specifically relating to teachers' pedagogies and pupils' attainment. It includes the following sections:

Section 1: Personal information including job title and outline of teaching commitments.

Section 2: Length of teaching experience and number of years using ICT.

Section 3: Frequency of use of a range of different types of hardware and software and the ways in which they are deployed.

Section 4: Teachers' views on the ease, advantages and disadvantages of using ICT in their teaching.

3.6.6 The focus group meeting and email conference

A focus group of seven of the teachers who were interviewed was held at King's College London, and an email conference was organised for those teachers who could not attend. The purpose of this meeting was to present to the teachers the emerging issues which we identified from the case study data on:

- teachers' perceptions of the value of the ICT activities they employ
- teachers' perceptions of their pedagogy
- teachers' perceptions of the relationship between different types of ICT use and their pedagogical practices.

A list of questions provided at the focus group meeting is given in Appendix 9. The feedback from the teachers provided confirmation of our conclusions and ideas for modifications to the pedagogical framework.

3.6.7 Method of analysis

The qualitative data were analysed using a similar technique to that used in the first ImpacT² project (Watson, 1993). Common strands and pedagogies were identified and related to different types of ICT use. The data from the questionnaire were used to illuminate the observational and other data. Profiles of each teacher have been written up to help us identify important pedagogical practices relating to ICT use and to compare findings with the published research evidence.

Note: It was only possible to gain snapshots of the ICT activities because of the short time-scale of the project, but these have revealed some key innovative pedagogical practices relating to current uses of ICT.

4 Pedagogical theory results of the literature review

This section presents a discussion of different pedagogical perspectives and theories derived from the literature review. There is clear evidence from our literature reviews that teachers' perceptions of pedagogy relating to ICT are often confined only to classroom practice. This section provides a broader base for the reader on what pedagogy involves and how this might apply to ICT use in teaching. The first step therefore was to review the use of the term 'pedagogy' and explain how its

²The first ImpacT project was a two-year study commissioned by the then Department for Education to evaluate the impact of ICT on children's achievements, and was published in 1993 (Watson, 1993). This work was then followed up by the ImpacT2 project, a study carried out between 1999 and 2002 which continued the investigation into the impact of ICT on educational attainment (Comber *et al.*, 2002; Harrison *et al.*, 2002; Somekh *et al.*, 2002).

relationship to practice may be observable in the classroom. This provided a definition of pedagogy and the identification of the aspects that were important for analysing pedagogy in relation to ICT use. For a more extensive review of pedagogy see Webb (2002).

4.1 What is pedagogy?

Watkins and Mortimore (1999), in a review of research literature on pedagogy, assert that conceptions of pedagogy held by researchers and academics have become more complex over time as our growing knowledge has become both more differentiated and more integrated. They argue that recent developments in our understanding of cognition and meta-cognition have influenced the conceptualisation of pedagogy. They describe the current model of pedagogy as a complex one:

'On the one hand it offers an increasingly integrated conceptualisation which specifies relations between its elements: the teacher, the classroom or other context, content, the view of learning and learning about learning. Such a model draws attention to the creation of learning communities in which knowledge is actively co-constructed, and in which the focus of learning is sometimes learning itself. This model of pedagogy would also be increasingly differentiated by details of context, content, age and stage of learner, purposes, and so on.' (Ibid., p.8.)

Alexander (1992) identifies teaching methods and pupil organisation as the two facets of pedagogy. These are included in Alexander's conceptual framework for educational practice (see Figure 4.1) where pedagogy is one of seven inter-related aspects of educational practice. Alexander describes the dimensions of his framework as a minimum list rather than a fully comprehensive framework.

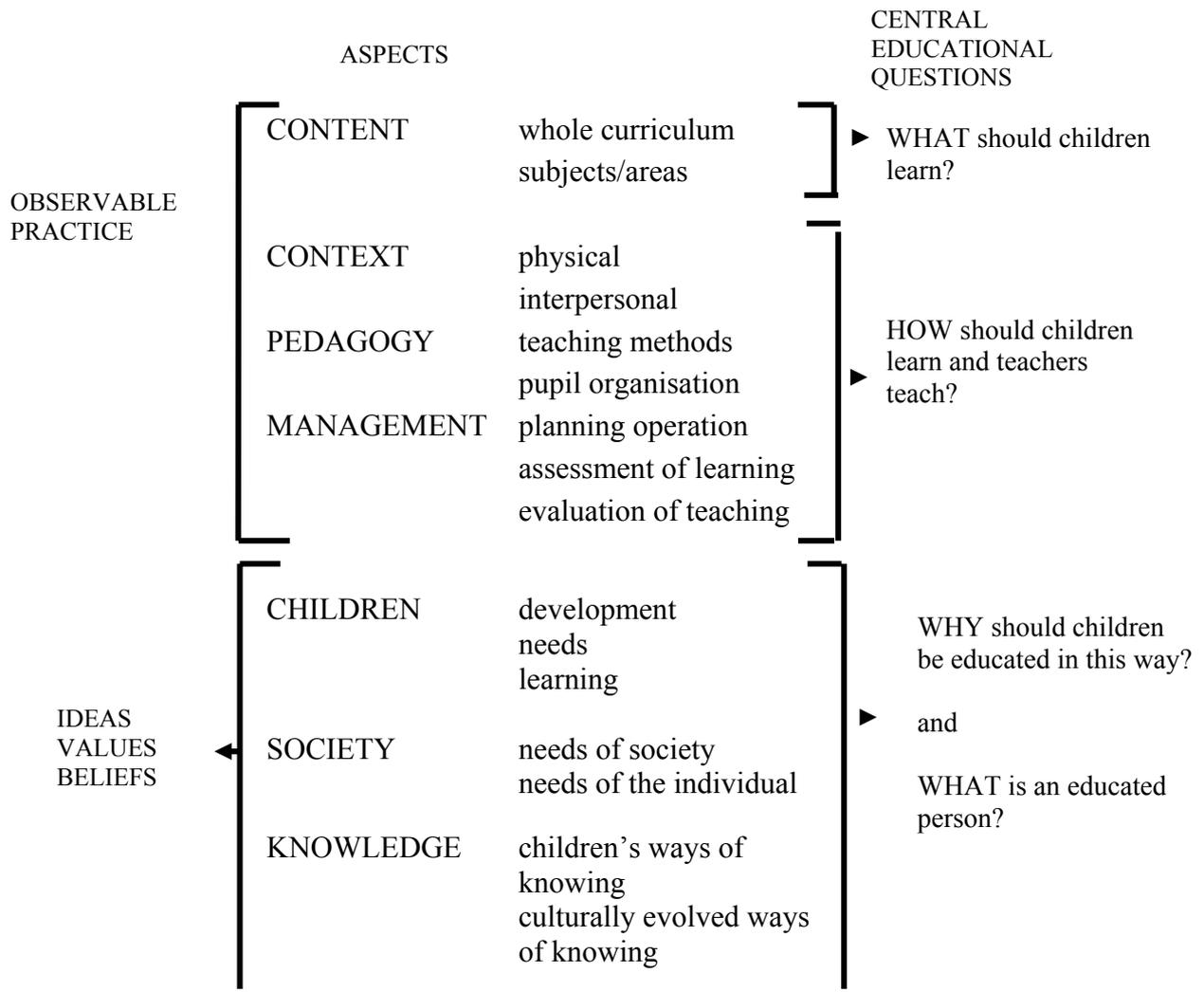


Figure 4.1 – Educational practice: a conceptual framework (Alexander, 1992, p. 184)

This framework implies that the pedagogy of ICT should be elucidated within a broad framework of educational practice. A further point to note from the framework is that what can be observed in the classroom is only part of educational practice. Thus, illuminating good practice in teaching and learning with ICT will require examining teachers' ideas, values and beliefs, and the thinking that leads to observable elements in practice.

4.2 Pedagogical reasoning

The processes of planning, teaching, assessing and evaluating, and the knowledge needed for these processes, are described in Shulman's (1987) model of pedagogical reasoning. Shulman focuses on knowledge rather than ideas and beliefs. Moreover, there is evidence that teachers' ideas, beliefs and values may also influence practice (Fang, 1996; Moseley *et al.*, 1999). Therefore both facets need to be considered. According to Shulman, teachers' knowledge bases include the following categories of knowledge:

- Content knowledge.
- General pedagogical knowledge (knowledge related to general teaching issues, eg teaching approaches, classroom management).
- Curriculum knowledge (knowledge about the 'tools of the trade': schemes of work, resources etc).

- Pedagogical content knowledge: ‘that special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding.’ (Shulman, 1987, p.8.)
- Knowledge of learners and their characteristics.
- Knowledge of educational contexts: groups, classes, the school and the wider community.
- Knowledge of educational purpose and values, and their philosophical and historical grounds.

This list matches many of the elements in Alexander’s list of aspects of educational practice and it includes, and further characterises, much of the knowledge that would be needed to inform those aspects. One of the implications from this model for teachers’ use of ICT is that teachers need to have sufficient knowledge about the topic or subject and how this will be affected by the use of ICT in order that they can make appropriate decisions about using ICT with their pupils.

Alexander (1992) suggests that in the UK we have focused more on content rather than pedagogy, and he argues that content and pedagogy are indissolubly linked. In order to explore this link, Shulman’s (1987) model of pedagogical reasoning focuses on the processes involved in teaching, including the transformation of knowledge and how it can be taught. An important component of knowledge in Shulman’s model is pedagogical content knowledge. Other researchers have adopted the term ‘pedagogical content knowledge’ and defined it for particular subjects, for example:

‘Pedagogical content knowledge refers to knowledge about a topic that enables improved teaching of that discipline. In science such knowledge involves an understanding of the ideas students bring to class, the context in which students apply their science knowledge, and the multiple models of the same topic used by students and experts in the various contexts of application.’ (*Ibid.*, p. 337.)

The implication for ICT in education is that since pedagogical content knowledge differs between subjects, the choice and use of ICT resources will differ in terms of pedagogical practices for different subject teachers. In some situations teachers may use their beliefs to filter their knowledge bases at the start so that during the processes of pedagogical reasoning they are only drawing on a limited subset of the knowledge base. Shulman’s model includes a range of pedagogical reasoning skills, which are listed below:

- Comprehension – examining the content to be taught and considering its inter-relationships with other subject content.
- Transformation – transforming ideas of knowledge
- Preparation – preparing the curriculum in relation to aims and objectives.
- Representation – thinking of ways that the ideas and skills may be made accessible to pupils.
- Adaptation – fitting the material to the characteristics of the pupils, taking account of age, gender, culture etc.
- Tailoring – fitting the curriculum and teaching plans to a specific group of pupils.
- Instruction – performing a variety of teaching and class-management activities.
- Evaluation – assessing the effectiveness of the teaching through the assessment of pupils as well as other types of evaluation.

Learning environments, particularly those based on multimedia approaches, are increasingly being described in terms of ‘affordances’,³ which focus on how the learning environment is perceived by the user (Laurillard *et al.*, 2000). Affordances are the properties of a system, as perceived by the user, which allow certain actions to be performed and which encourage specific types of behaviour. Affordances may be similar to scaffolding⁴ but may be a more useful way of conceptualising aspects of the system, as scaffolding suggests something additional, possibly external to the system, where affordances may be integrated into the system.

³ Affordances are the properties of a system as perceived by the user which allow certain actions to be performed and which encourage specific types of behaviour.

⁴ Scaffolding is where pupils build up knowledge and understanding by linking new concepts to those previously understood through a mental framework of linking concepts.

Linn and Hsi (2000) report on a collaborative project that has investigated these pedagogical issues for science education within ICT classrooms and produced a list of 'pragmatic pedagogical principles':

- Encourage students to build on their scientific ideas as they develop more and more powerful and useful pragmatic scientific principles.
- Encourage students to investigate personally relevant problems and revisit their scientific ideas regularly.
- Scaffold scientific activities so students participate in the enquiry process.
- Model the scientific process of considering alternative explanations and diagnosing mistakes.
- Scaffold students' feedback to explain their ideas.
- Provide multiple visual representations from varied media.
- Encourage students to listen to and learn from each other.
- Design social activities to promote productive and respectful interactions.
- Scaffold groups to design criteria and standards.
- Employ multiple social activity structures.
- Engage students in reflecting on their scientific ideas and on their own progress in understanding science.
- Engage students as critics of diverse scientific information.
- Engage students in varied sustained scientific project experiences.
- Establish an enquiry process which can be generalised and is suitable for diverse scientific projects.

Linn and Hsi (2000) found that each student drew on different pivotal cases to sort out their thinking. For each class the teacher needed to research students' understanding, analyse their thinking and identify pivotal cases that would build on students' ideas and inspire them to reflect and restructure their views. The teachers then had to use these pivotal cases at appropriate times in discussion with the students. For example, a student that believes that metals have the capacity to impart cold would be asked 'How do metals feel in a hot or cold car?'

Assessment is one of the most important and difficult aspects of the educational process, especially where the learning has involved ICT, and there is much research evidence to show that the everyday practice of assessment in classrooms is beset with problems and shortcomings (eg see Black and William, 1998). This adds to the problems of measuring attainment which is attributable to ICT because the pupils are often not assessed in these activities, other than through the products they produce at the end of ICT-based lessons.

4.3 A teacher-centred or pupil-centred pedagogy

Shulman's model has been criticised for leaning on a theory of cognition that views knowledge as fixed and external, and on a teacher-centred pedagogy (Banks *et al.*, 1999). Because the model does not incorporate the pupils' thinking processes and does not provide a basis for analysing pupil-teacher interactions, then it may fail to address the important experiences resulting from ICT use. Understanding or identifying the thinking processes of the learners, as far as possible, is particularly important for new technologies as research has shown that new ways of learning and new representations are introduced to pupils through ICT.

'Students can literally initiate the process, proceeding by discovering, inventing, or inquiring, to prepare their own representations and transformations. Then it is the role of the teacher to respond actively and creatively to those student initiatives. In each case the teacher needs to possess both the comprehension and the capacities for transformation. In the student-initiated case, the flexibility to respond, judge, nurture, and provoke student creativity will depend on the teacher's own capacities for sympathetic transformation and interpretation.' (Shulman, 1987, p. 14.)

This idea of pupils initiating the learning process relates closely to teachers believing that they are often only facilitators in the learning process involving ICT. As can be seen by the above discussion, pupil-led ICT activities in the classroom do not cover all aspects of pedagogy which teachers need to embrace in order to devise and follow through worthwhile learning experiences with the use of ICT.

4.4 ICT and the changing nature of pedagogy

Researchers' and academics' conceptualisation of pedagogy has changed in tandem with recent developments in our understanding of cognition and meta-cognition (Watkins and Mortimore, 1997). Many writers have also suggested that developments in ICT provide very different learning opportunities, and a need to design a new 'integrated pedagogy' has been identified (Cornu, 1995). For example, McLoughlin and Oliver (1999) define pedagogic roles for teachers in a technology-supported classroom including setting joint tasks, rotating roles, promoting student self-management, supporting meta-cognition, fostering multiple perspectives and scaffolding learning. An assumption here is that the use of ICT is changing the pedagogical roles of teachers, and a compelling rationale for using ICT in schools is its potential for a catalytic effect in transforming the teaching and learning process (Hawkrigde, 1990). The processes described by Shulman will still be necessary, but the decisions and outcomes from those processes may be different as teachers' knowledge, beliefs and values change in line with affordances provided by new technologies.

A dynamic model for such a transforming pedagogy for IT was derived from the PALM Project (Promoting Anywhere Learning with Mobile computing; Somekh and Davies, 1991). They identified the dimensions of pedagogical change as:

- 'from a view of teaching and learning as discrete, complementary activities to an understanding that teaching and learning are independent aspects of a single activity
- from a sequential to an organic structuring of learning experiences
- from individualised to communicative learning
- From a view of the teacher's role as an organiser of learning activities to one as a shaper of quality learning experiences
- from a preoccupation with fitting teaching to a group, to a knowledge that teaching needs to be suited to individuals, which calls for continual self-monitoring to ensure sensitivity to unintended forms of bias and discrimination
- from a view of the learning context as confined to the classroom and controlled by the teacher to one of the learning context as a supportive, interactive, whole-school culture
- from a view of technology as either a tutor or a tool to one where it is part of a complex of interactions with learners, sometimes providing ideas, sometimes providing a resource for enquiry, and sometimes supporting creativity.' (pp. 156-157)

The theories discussed in this section provide the foundation for our analysis of the empirical evidence discussed in the next section, and they are referred to where relevant in the analysis and discussions.

5 Empirical evidence of pedagogical practices

The second focus of the literature review was on the empirical evidence which we collected from many studies, and the focus of this section of the report is on the relationship between attainment and pedagogical practices involving the uses of ICT. The studies that have contributed to this review can be classified into six main groups:

- Bibliographies/literature reviews/meta-analyses. No reviews that focus specifically on pedagogy for ICT use at school level were found, but several articles in this category made some analysis of pedagogy. For example, Draper (1998) reviewed evaluations of software in use in higher education settings that were associated not just with satisfactory learning but with demonstrable improvements. A review by Scanlon (2002) that aimed to develop understanding of technology-mediated practical work in science within higher education drew on studies at secondary school level.
- Studies of effective teaching and of teachers' views that address issues associated with pedagogy, but do not focus on and generally make little reference to ICT use (eg see Askew *et al.*, 1997). A small number of recent studies in this category are discussed briefly because recent research on the contribution of ICT to attainment shows that ICT is effective only when combined with good teaching.

- Short-term interventions associated with software design in which a specific aspect of ICT use, for example a particular software application or a feature of software, was introduced to pupils and evaluated (see Lavonen *et al.*, 2003). Many of these focus mainly on the interaction between the computer and the pupils rather than considering the role of the teacher and of peers. Only those that address pedagogical issues are discussed. They may involve a few hours' or a few weeks' work. Despite the very short-term nature of the studies, some provide useful evidence of specific affordances of ICT and how they enable learning objectives to be achieved.
- Studies associated with the introduction of an additional general ICT resource such as laptops or the availability of the internet in science lessons. Many of these studies are looking for a wide range of effects and they may or may not involve teachers' professional development. Some reports yield disappointing results; for example Jarvis *et al.* (1997) evaluated the effect of collaboration via email links on the quality of 10- to 11-year-old students' scientific investigative skills in six rural primary schools and found no real indications that the use of email enhanced scientific learning. In this case the study encountered problems with hardware, software and the teachers' abilities.
- Studies focused on specific aspects of pedagogy in specific subjects involving development work with ICT over two to three years (eg see Moseley *et al.*, 1999)
- Longitudinal studies involving development work, usually over at least five years, eg Linn and Hsi (2000). These studies address the changing nature of teaching and learning associated with the introduction of technology.

5.1 Studies of effective teaching

The process of instruction as described by Shulman (1987) involves performing a variety of teaching and class management activities. In general terms much of this is observable and documented in the research literature on effective teaching. For example the Hay McBer report to the Department for Education and Employment (Hay McBer, 2000) has been particularly influential in the UK. The literature on effective teaching, including the Hay McBer report, makes very little reference to the use of ICT.

In summary, the Hay McBer report looked for characteristics of teachers that were associated with pupils' good progress. They found that the progress of pupils is most significantly influenced by a teacher who displays both high levels of professional characteristics and good teaching skills, which lead to the creation of a good classroom climate. They identified characteristics of good teachers as:

Professionalism:

- Challenge and support
- Confidence
- Creating trust
- Respect for others

Thinking:

- Analytical thinking
- Conceptual thinking

Planning and setting expectations:

- Drive for improvement
- Information seeking
- Initiative

Leading:

- Flexibility
- Holding people accountable
- Managing pupils
- Passion for learning

Relating to others:

- Impact and influence
- Team-working

Understanding others

In relation to the model of pedagogical reasoning, there are some aspects of the Hay McBer report of particular interest. Many of the characteristics relating to professionalism are based on beliefs and values. The 'thinking' characteristics of teachers are described as including the complex analytical thinking required for planning and evaluating, and this conceptual thinking links to the transformation process. For example at the highest level the teacher:

'Makes the complex simple

Helps pupils and others to understand something complex by finding a new and creative way to explain it in simple terms.' (*Hay McBer, 2000, p. 47.*)

It is interesting to note that the development of pupils as independent learners, an ability that is often considered to be crucial for making effective use of ICT, and which is categorised under 'passion for learning', is only demonstrated at the highest level:

'[the teacher] motivates pupils to learn independently

Continuously provides pupils with opportunities to experience learning as enjoyable and satisfying, to increase their self-motivation. Consistently provides a range of opportunities for pupils to direct their own learning; provides independent learning options, and enables pupils to access these. Encourages self and peer evaluation. Builds pupils' capacity to question themselves.'

(*Ibid.*, p. 61.)

According to Brown *et al.* (2001) the Hay McBer study is likely to be flawed, but it does provide a set of general characteristics that were certainly associated with some effective teachers.

Moseley and Higgins (1999a,b), in a study of primary school teachers known to be achieving either average or above average gains on measures of relative pupil attainment, focused on pedagogy using ICT and also found a very complex picture in which it was difficult to characterise effective teachers using ICT. The teachers were supported in developing their practice in literacy and numeracy using ICT. The project explored links between teachers' thinking about their teaching behaviours or actions in the classroom and pupils' learning gains. The work indicated that a key feature of the more effective teachers was their use of effective explanations. Observations showed that teachers used examples and counter-examples and involved pupils in explaining and modelling to the class. Teachers who favoured ICT were likely to have well-developed ICT skills and to see ICT as an important tool for learning and instruction. They were also likely to value collaborative working, enquiry and decision making by pupils.

5.2 Studies of teachers' views of pedagogy

Watkins' and Mortimore's (1999) review of research into practitioners' views on pedagogy suggested that teachers recognised the complexity of pedagogy and the multi-dimensional nature of classroom life. Watkins and Mortimore (*Ibid.*) identified some tensions between the review of pedagogy in the academic and research literature and the views of practitioners. In particular, while the trend among researchers and academics has been moving towards a model that supports the active construction of meaning and endeavours to help learners learn about learning, teachers may adopt a simplified model of practice in the face of contextual constraints.

Loveless (2000) in an investigation of teachers' pedagogy for using ICT to support the development of visual literacy, also found that key issues were the tension and contradictions in the cultures that influence classroom practice. She used a qualitative, interpretive approach employing ethnographic⁵ techniques to investigate pedagogy, but also found the need to take account of the cultural, political, emotional and moral experience of the teacher engaging with teaching and learning in the digital arts. Survey methods for measuring pedagogical content knowledge are being developed, but the multi-faceted nature of the knowledge and the fact that much still needs to be learned about its nature makes this a difficult task (*Rowan et al., 2001*).

⁵ Ethnography is a form of research which focuses on the sociology of meaning within a particular community. Members of the community are interviewed with a view to revealing the common cultural understandings related to a specific topic.

Studies that examine specific aspects of teachers' detailed knowledge of learners and their misconceptions require careful investigation of pupils' learning compared with teachers' predictions of their difficulties and misconceptions. For example Hadjidemetriou and Williams (2001) propose a methodology that will help to bridge the gap between pupils' difficulties and teachers' perception of these difficulties. They devised a diagnostic assessment instrument to elicit pupils' misconceptions of graphing and used it as a questionnaire for teachers.

5.3 Pedagogies for different subjects in primary schools

In the discussion of the theoretical foundation of teachers' pedagogies (see Section 4), subject-specific interpretations of pedagogy are explained using examples of principles that have been elucidated for pedagogies for science and mathematics. Each subject may have its own interpretation of pedagogical principles and pedagogical content knowledge. Empirical studies are now discussed under headings related to subject areas within each major phase of education, and then emerging themes that occur across subjects and phases are identified and discussed subsequently.

5.3.1 ICT in primary education

There is some evidence that ICT helps primary school teachers to be more effective in their teaching (Becta, 2003), especially if they are well resourced (Becta, 2001). Ofsted's inspection judgements in 2,582 primary schools have been compared with achievements of schools at Key Stage 2. The Becta (2003) report concludes that there are strong links between good use of ICT resources and attainment in ICT and other subjects. However, although this is a statistically significant relationship, there are no proven causal links. The results may well be due to other factors such as good leadership and general quality of teaching. It is also unclear exactly how 'good use' is defined or indeed whether there is any general agreement on what constitutes good use.

Findings of a research and development project, which investigated effective pedagogy when using ICT in literacy and numeracy in primary schools (Moseley *et al.*, 1999), provide illustrations of teachers' practices at that time and the complexity of choices which teachers made in deciding when, when not, and how to use ICT to strengthen their teaching. Teachers were selected in terms of the relative performance of their pupils, the provision and use of ICT and their attitude towards the technology. It was concluded that, even in 1997-98, many primary school classrooms still only had regular access to one or two computers, and this affected the choices teachers were able to make about using ICT.

Moseley *et al.* (1999) used pre- and post- standardised tests to check improvements in pupils' attainment. Part of the development work involved an exploration of the links between teachers' thinking, their teaching behaviours or actions in the classroom and pupils' learning gains. It was found that teachers' thinking and beliefs about teaching and learning were linked to what they did in the classroom and the choices they made in selecting how to integrate ICT into their teaching. A key feature of the more effective teachers was their use of effective explanations. Teachers who favour ICT are likely to have well-developed ICT skills and see ICT as an important tool for learning and instruction. They are also likely to value collaborative working, enquiry and decision-making by pupils. Teachers who have reservations about using ICT are likely either to exercise a higher degree of direction or to prefer pupils to work individually.

The value of support from the headteacher or a collaborative working environment was acknowledged. As new equipment and software become available, teachers will need to develop new skills and pedagogical approaches. The authors suggest that the task of developing teachers' effectiveness in using ICT is a long-term goal and needs to become established as a regular part of their professional development. An important issue, it would seem, is training primary school teachers to make best use of ICT in the classroom.

An early study (Murray, 1992) examined primary teachers' interpretations of the National Curriculum guidelines for use of technology. Results of a questionnaire, sent to 200 teachers in 27 randomly selected schools, showed that word processing was the most frequently used software and that spreadsheets were used by only 8 per cent of respondents. This is supported by the more

recent survey conducted by Preston *et al.* (2000) of 100 IT teachers. They found that over 90 per cent of IT teachers used word processing more frequently than once a month, but that none of the other generic applications was used this often. Murray (1992) recommended, therefore, that there was an urgent need for appropriate in-service training. The need to provide in-service training was exacerbated by newly qualified primary school PGCE students entering teaching with limited training in ICT and being reliant on school support to develop further their use of ICT (Kay and Mellar, 1994).

According to government statistics, the situation has improved considerably over recent years. A recent large-scale survey of over 1,800 primary, secondary and special schools (Skills, 2001), found that 75 per cent of teachers felt confident in using ICT, 78 per cent had received some training and 71 per cent had updated their training in the last two years. However, there was no evidence of actual use of a range of ICT packages in their regular teaching from this survey. Nor did the survey method identify whether teachers were thinking of only a narrow range of ICT uses, ie word processing and presentations, when answering the question about confidence using ICT.

Since the National Grid for Learning was introduced, access to the internet within all schools has become established. Early work into teachers' opinions and ideas about ICT established some key factors which were necessary to enable teachers to acquire network literacy and to become adept users. It was concluded that the successful implementation of ICT and effective educational practice were ultimately dependent on the professional development of teachers (Dawes, 2000).

Innovations in which schools and teachers have been provided with portable computers have met with limited success. A review of the literature for the Evaluation of Digital Opportunities projects in New Zealand focused on international and New Zealand ICT initiatives in upper primary and secondary schools since 1990 (Boyd, 2002). This provides a useful review of laptop innovations. The author suggests that aside from the:

'lack of validity of the qualitative measures used to assess student achievement, there are two possible reasons for the reported lack of impact. One is that the use of laptops does not in fact have any effect on student achievement. The other, perhaps more likely reason, is that changes to student achievement are conditional on context, changes are due to a complex interplay of factors such as teachers changing their pedagogical approaches to support a more student-centred environment in which ICT use is integrated into the curriculum. If this does not occur and laptops are used within the traditional classroom environment simply as word-processors and presentational devices, then it is unlikely that improvements in student achievement or changes to classroom environments will be reported.' (*Ibid.*, p. 30.)

Research into pupils' perceptions of computer use in Welsh primary schools (Selwyn, 2001), has shown that far from being overwhelmingly positive about using computers, children were far more discerning about the potential advantages and disadvantages. So, for example, while they appreciated the benefits of spellcheckers and other similar tools, they were aware of a negative impact on creativity in drawing and story writing. In some cases they believed that having a perfect looking end product somehow diminished their right to be identified as the unique isource of the text.

Research has shown that there is a clear gap between the type of use made of the computer in the home and that made in the school. Based on qualitative and quantitative data collected from a sample of years 3 and 5 pupils from three primary schools, it was found that the most frequent activity at school was word processing, which pupils found boring, while the most popular use at home was for playing games (Mumtaz, 2001). The author suggests that schools should learn from what works at home and allow pupils to work on activities that they find valuable, motivating and worthwhile.

It must be acknowledged that while many primary school children could be considered to be sophisticated and knowledgeable users of ICT, their access to the technology at home is varied (Selwyn and Bullon, 2000). In their study of 267 year 2 and 5 children in South Wales, the authors found that although the majority of pupils reported making some use of computers in schools, patterns of sustained use and varied engagement with ICT were rare. Writing was most widely experienced and drawing the most regular activity. Given that home use is variable, the authors

argue that the paramount role of schools should be to balance the demands of the computer 'haves' with the 'have lesses'.

Organisation

It is widely acknowledged that teaching strategies are a crucial factor, and these can be greatly influenced by the organisation of ICT facilities. A report from a one-year project in nine primary, one secondary and one special school, which experienced a variety of ICT uses, found a large variation between schools and between classes in the same school. It was found that a whole room of integrated learning systems forced a particular kind of organisation, while a 'mini suite' of 10 computers in a class enabled the teacher to structure the use of ICT within the curriculum and support the pupils to be more independent and reflective learners. In another study of three primary schools, Goodison (2002) confirmed that a range of organisational features, such as a sound learning environment, the commitment of the headteacher and good forward planning, were correlated with successful implementation, and the commitment of staff played a pivotal role in the process. However, as Goodison pointed out, this commitment can always be compromised by technological change if the process of implementation is not managed properly.

Group work

There is little evidence in the literature to indicate that collaboration actually enhances learning per se. Jarvis *et al.* (1997), for instance, evaluated the effect of collaboration by email on the quality of 10- to 11-year-old pupils' scientific investigative skills in six rural primary schools. Although the children were seen to demonstrate a variety of scientific skills, in particular observing and recording, and they were seen to develop some general computer skills, there was no indication that the use of email actually enhanced their scientific learning. As has been alluded to earlier in this section, the influence of the teacher was recognised as a crucial element in the process. In instances where teachers provided limited supervision and guidance there were often periods of unproductive activity. Teachers with more confidence in science tended to monitor activities more closely and intervene more, as a result of which pupils extended their scientific skills.

As Eraut (1995) has pointed out, group work is a complex process which limits generalisation. Evidence from 19 case studies in 16 classes of 8- to 12-year-olds offered strong support, however, for a Vygotskian⁶ rather than a cognitive conflict⁷ explanation of the benefits of group work among pupils.

According to Yu (2001), there is evidence that while having pupils work in co-operative learning environments may, in itself, have no additional impact on learning, an element of competition may have some effect on outcomes. In a study of 192 fifth-grade students (aged 11–12 years) in six classes in one Taiwanese primary school, the author examined the effect on pupils' cognitive, affective and social outcomes of embedding the element of competition in computer-assisted co-operative learning situations. The statistical analyses of the results showed that co-operation without competition engendered better attitudes towards subject matter and promoted more interpersonal relationships. The study concluded that constructive interactions among pupils and affective and social development would be enhanced by co-operation without inter-group competition.

Collaborative learning in children of primary school age is considered to be beneficial, but effective pupil collaboration is rare (Crook, 1998). Studies of pupils using ICT also suggest that effective pupil collaboration for learning is not easily achieved (Crook 1998).

⁶ Vygotsky's sociocognitive theory emphasises social, cultural and contextual influences, and is based on the idea that learning is a process of internalising social and cultural values. Learning therefore takes place when there is social interaction and agreement between learners.

⁷ Piaget argued that cognitive conflict is the principal mechanism for learning. This conflict occurs when there are disagreements between learners regarding their understanding of a problem, which are then resolved through teacher-led discussion.

5.3.2 ICT in primary mathematics and numeracy

As has been shown in the attainment literature review (Cox and Abbott, 2004), there is much reported research into the uses of ICT in mathematics teaching at both primary and secondary levels. Some large-scale studies investigate the effects of a range of ICT environments and others focus on specific uses of ICT, as is explained in this section. There is clear evidence of the positive effects of ICT being associated in many cases with the particular pedagogies of the teacher and also with the relevance of the ICT activity to the curriculum.

Large-scale projects

The first ImpacT study (Cox, 1993) was a large-scale investigation into the effects of ICT on children's achievements, which focused in part on ICT and mathematics in primary schools. The research methods related to an assessment of pupils' achievements of specific learning tasks and skills, and in-depth longitudinal case studies in a few high-IT classes focusing on classroom processes, IT resourcing and use monitored throughout the two years of the field work. The project found that ICT did have a positive impact on children's achievements, but the effect was not consistent across all subjects or age bands. The methods to measure pupils' attainment included pre- and post-tests, case studies and semi-quantitative analysis, and the results did show a positive effect for mathematics in the 8–10 age range (see also Johnson *et al.*, 1994). To measure learning gains more exactly the project also devised a series of mini-studies with assessment techniques which matched the concepts and skills being learned. These provided additional evidence of positive effects of ICT on attainment, eg mathematical reasoning using Logo, and Boolean logic skills using databases. The conclusions were that 'effective use of IT required substantial demands in terms of (teachers') knowledge and understanding of, and familiarisation with, a variety of software in order to integrate the activity, in philosophical and pedagogical terms, with a larger scheme of work.' (Ibid., p. 3.)

In a study of four different school districts with very different student : computer ratios (Alspaugh, 1999) it was found that there was no difference in the educational performance in three subjects, one of which was mathematics. The conclusion was that as the performance was no worse with high computer use, the computer education and any other educational advantages were a bonus. The reason why the use of ICT did not enhance the attainment in the subjects was not addressed. Instead it is suggested that there might be other 'desirable educational outcomes associated with the use of computers that can be identified and measured that are beyond the traditional educational outcome measures.' (Ibid., p. 149.)

Another large study (Waxman and Huang, 1996) examined whether classroom interaction, selection of activities, instructional activities or organisational setting of classroom, or student on-task and off-task behaviour in classrooms significantly differed according to the degree of implementation of technology in mathematics classes. The subjects were 2,189 middle school students. The results indicated that there were significant differences in classroom instruction determined by the amount of technology used. Instruction in classroom settings where technology was not often used tended to be whole-class approaches where students generally listened or watched the teacher. In classrooms where technology was moderately used there was much less whole-class instruction and more independent work. These findings support the notion that technology use may change teaching from a traditional teacher-centred model to a more student-centred instructional approach. Another important finding from this study was that students in classrooms where technology was moderately used were found to be significantly more 'on task' than in the other two groups. The results from this study show, therefore, that the technology can change the pedagogical practices of the teacher to a more student-centred approach. Other changes in teaching may also take place, as considered in the following section.

Topic-specific ICT in small studies

Much of the research literature is based on small-scale studies of children in a narrow learning context, and it generally shows that there is some improvement in performance of a limited set of tasks. Falling into this category of study is a study by Ainge (1996) of very small poorly matched groups of disadvantaged pupils, in which the learning of shapes using virtual reality was compared with learning using cardboard models.

In a meta-analysis of many focused studies, Clements (2000) describes the unique contribution of computers to problem- and project-oriented pedagogical approaches. His research showed that pupils' collaborative activities resulted in enhanced achievement. An increase in collaboration between pupils resulted in 'deep' conception, and a perception of learning as dependent on thinking and understanding. Control groups possessed 'shallow' conceptions of learning, seeing it as a matter of paying attention, doing assigned work, and memorising. Such results could, however, be independent of ICT use since the effectiveness of computer software is likely to be dependent on the pedagogical context within which it is used (Hoyles, 2001).

Another convincing experiment, but with a very small sample (McFarlane *et al.*, 1995), introduced line graphs to 8-year-old children, using data logging. Children who had been exposed to data logging showed an increased ability to read, interpret and sketch line graphs when compared with children using traditional apparatus. The results suggested that the manual plotting of points as a first introduction to graphs appeared to interfere with understanding.

With regard to small-scale studies, it is worth bearing in mind the conclusions from a useful review of work on mathematical achievement using technology and on supportive teaching and learning environments using technology (Hennessy and Dunham, 2002). The review points out that studies involving contrasting control and experimental groups using technology are fraught with difficulties because complex factors arising (particularly teachers' behaviours and pedagogy) are rarely accounted for, hence fair comparisons using test scores alone are almost impossible. ICT itself can play an important role in shaping the mathematical activity.

Programming and micro worlds

One of the most widely researched areas of ICT in mathematics is programming and the use of micro worlds. Many studies have reported the use of the programming language Logo with primary school children. The use of Logo has been shown to improve children's estimation of distance (Campbell *et al.*, 1991) and ability to create accurate delayed instructions to follow a maze (Johnson and Kane, 1992). It is suggested that Logo training and experience in programming have a beneficial effect on children's higher level cognitive skills such as problem solving (Au and Leung, 1991).

In a meta-analysis of research on Logo, Clements (2000) identified a range of attributes which related to pupils' use of Logo. If 'used appropriately, computer programming has been shown to help students:

- develop higher levels of mathematical, especially geometric thinking
- learn geometric concepts and skills, including two dimensional figures, angles, symmetry, congruence, and geometric motions, although teacher guidance is important
- gain "entry" to the use of the powerful tool of algebra
- develop concepts of ratio and proportion
- form more generalized and abstract views of mathematical objects;
- develop problem solving abilities, especially particular skills (eg problem decomposition, systematic trial and error) and higher level metacognitive abilities
- enhance the social interaction patterns though there may be gender considerations with groups of young children using Logo collaboratively.' (Yelland, 2003 pp.28-29)

In a study of primary school pupils using Logo, Cope and Walsh (1990) found that for pupils who spent a long time programming there was 'the habituation to sustained intellectual activity' (p.126) and a subsequent spin-off to other activities in the curriculum. However some problems may arise (Cope *et al.*, 1992) if too little time is spent with pupils with too little prior mathematical knowledge, for example when considering the difference between internal and external angles when drawing simple closed shapes.

There is some controversy in the teaching of Logo as to how much learning by autonomous discovery should be expected of pupils. Hoyles and Noss (1992) argued that it is being 'too optimistic to ground pedagogy on a series of accidental encounters. The least we can do is encourage such meetings.' (p.56) There is a need to provide a tight framework within which pupil autonomy and mathematical expression can take place, and for the teacher to bridge the differences in discourse between Logo environments and school mathematics.

Results from one study pointed out that evaluation of success was internally determined in the Logo environment, though students still sought external approval, and that Logo may foster cognitive growth in part by engendering effective motivation (Nastasi and Clements, 1994). When learning about variables in a Logo environment, there is a need for the teacher to be aware of and be explicit about using a Vygotskian approach, since such concepts cannot be taught directly (Sutherland, 1993). The theme of being explicit in teaching is taken up by findings which support claims for the efficacy of Logo as a medium conducive to the teaching and learning of problem solving, but only when particular problem-solving skills are explicitly taught (Swan, 1991).

A teaching experiment with just two pupils, very closely observed, showed that a concept such as fractions could be built into the context of a micro world. Here the role of the teacher was essential to introduce the wording and language of fractions at the appropriate time in the learning process (Tzur, 1999). One important outcome was the highlighting of the importance of the need to articulate how the teacher could proactively support children's construction of conventional ways of symbolising in specific areas.

Internet use

School web pages and reports by Becta, local education authorities and the media reveal a growing use of the internet in primary schools, but there are not yet many completed research projects investigating the direct effects on teachers' pedagogies and pupils' attainment.

There are websites that cater for teachers' and pupils' needs, which might help teachers to acquire the skills and competencies discussed above. For example, the NRich Prime website (www.nrich.mathematics.org.uk/prime) has a comprehensive variety of resources including open-ended investigations, problems, games, activities and articles that could enrich children's mathematical experiences. Again, due to lack of research into the effects of using resources over the internet, there is little evidence that using such a resource mediated through the use of ICT does make teachers more effective.

One piece of research (Jones and Simons, 1999) evaluated the NRich website as it was five years ago, but the evidence from this failed to estimate the usefulness of the site for primary school teachers. The questionnaires returned from primary school pupils were only 15 per cent of the total, and the data for the different age ranges were not presented separately. Only one primary school pupil, who used the website from home, was followed up. A third of the 999 teachers responding to the questionnaire were in primary schools, although most of them accessed the site about once a month or less. Again most of the data are not presented separately for the different phases, but two-thirds of all respondents said they used the website mainly as a source of problems to use in their teaching. It would appear, therefore, that this is a resource that could encourage a move towards more effective teaching of mathematics in primary schools. More data specific to the pedagogy of primary school mathematics teaching when using such websites is needed. New research should examine both the pupils' use and the teachers' use of such a resource for both teaching and learning, and its effectiveness in affecting learning outcomes.

5.3.3 The state of mathematics and ICT pedagogy in practice

Evidence from many of the studies discussed above shows first that the effective use of ICT requires teachers to have a substantial knowledge and understanding of the ICT resources and be familiar with a range of applications in order to be able to integrate ICT into their mathematics teaching. The ICT uses should enable pupils to think mathematically, develop significant mathematics strategies, connect mathematical ideas with the real world and focus on reasoning rather than on answers.

The research showed that when teachers used ICT which challenged pupils' thinking and engaged pupils in investigations there was a consequent higher order of mathematical reasoning and raised attention than when teachers adopted a 'transmission' view of teaching. 'The teachers' actions in orchestrating students' integration with the task, the technology and their peers proved to be crucial to their success in finding a solution.' (Goos *et al.*, 2003.)

Connell (1998) concluded that the technology should be used in a tightly linked fashion and should be supportive of the underlying instructional approaches. It should also be used as a tool for student use in creating their own personally meaningful representations. The presence of the computer alone as a delivery system of static expert representations does not guarantee, and indeed may inhibit, the development of student representations.

To conclude, in order to meet the requirements above, it is apparent that teachers of primary school mathematics need to have available a repertoire of approaches to the use of ICT, depending on the context and the mathematical purpose, and a substantial knowledge of the ICT environments they are using.

5.3.4 ICT in primary English and literacy

Based on research into the use of computers in English over 15 years, the use of ICT in primary English has been found to support collaboration, creativity, independent learning and reflection in pupils (Twedde, 1997).

The preliminary results of a survey designed to identify how talking book software was being used in the classroom, and which additional features could be beneficial in future designs (Lewin, 1998), highlighted the success of this type of software for both early readers and those older children experiencing difficulties in learning to read. However, many teachers reported that they would like to see future implementations of the software enhanced with the provision of additional reinforcement activities which would enable the software to meet the needs of individual learners more effectively. A questionnaire sent to teachers in 1,230 schools had a relatively low response rate of 30 per cent (494 completed questionnaires were received from 371 schools). The majority of respondents were using talking book software. The results showed that the software was used mainly with pairs of children (82 per cent), but occasionally with individuals (29 per cent). A smaller number of teachers specified that the software was usually used by groups of three or more children at one computer (11 per cent). Use in groups or pairs was more commonly associated with early readers who were progressing normally. Most of the children were able to use the software independently with minimal adult support after receiving some initial training. Several of the classes that involved older children experiencing difficulties learning to read, or those identified as having special needs, worked with an adult for the duration of the session.

In primary schools the word processor is most frequently used for literacy (Mumtaz and Hammond, 2002). In this context, much of the work is individualised and is largely for presentational purposes, ie mainly typing up texts written initially by hand. There was little teacher intervention in the activity reported by these researchers. They concluded that schools are a 'long way from seeing the use of the word processor embedded...to support pupils' writing' and that 'teachers need more time for reflection on their learning objectives.' (p. 346)

Research reported by the first ImpacT Project (Watson, 1993) into teachers' uses of ICT in primary English found teachers using a range of software, including word processing. However, there was a conflict between teachers wanting to help pupils progress in their writing by the use of word processing, for example, and the desire of teachers to ensure that all pupils had equal 'turns' at the computer. This resulted in some classes of pupils only having about five minutes' use of word processing per pupil per term. The result of only having one computer in the classroom and wanting to provide equal access to pupils led the teacher into totally inappropriate practices where pupils first hand-wrote their stories and then typed them onto the computer in pairs. This finding is supported by more recent research evidence from the ImpacT2 project case studies (Comber *et al.*, 2002). The results showed that, again, because of the limited number of computers in the primary school classrooms, the sustained and regular use of ICT, such as for word processing, which has been shown to improve pupils' writing and reading skills rarely occurred. An important implication for teachers' pedagogies here is the decisions they need to make to enable pupils to have frequent and substantial access to ICT to be able to have any worthwhile benefit.

5.3.5 ICT in primary science

As is shown in the related report on ICT and attainment (Cox and Abbott, 2004), the most extensive and long-term developments in, and uses of, ICT in education have been in science at both primary

and secondary levels. This can be seen through different types of ICT environment such as simulations and modelling, as is explained below.

Simulations

ICT provides opportunities for pupils to explore simulations in the classroom where previously, without the use of ICT, they would have needed to travel to a science centre or museum, or the scientific process would have been impossible to study in the classroom for practical or safety reasons. There is a whole area of pedagogy that needs to be explored concerning the relationship between school-based and museum-based learning, but that is beyond the scope of this report. Of particular interest for this review is whether, and to what extent, ICT-based simulations can substitute for advanced experiments or experiences in a museum or centre.

Baxter and Preece (2000) found that the learning of 48 pupils in years 5 and 6 (9- to 11-year-olds) with the aid of computer planetaria was equally effective compared with learning with dome planetaria.

Modelling

Another important aspect of ICT in science at both primary and secondary levels is modelling, in which pupils build their own models by identifying relevant factors and variables and hypothesising relationships. Most of the research in this area focuses on learning and attainment (Cox and Abbott, 2004), but large projects such as the London Mental Models project (Mellar *et al.*, 1994) have also studied the role of the teacher in the classroom relating to pupils building scientific models. This study and others showed that although primary school pupils could investigate existing models and hypothesise relationships, it was more difficult for them to build their own model without the guidance and support of the teacher. They tended to build very basic models, and could not decide on strategies for further work without being told about the goals that they were trying to achieve (Ibid.)

5.3.6 ICT in primary ICT

A review of the literature (Webb, 2002) reveals that there is very little research into the pedagogy for teaching ICT, and how skills and understanding in ICT develop in children. Wood (2001) argues that there has been much 'woolly thinking' about teaching ICT and the knowledge that learners need. He argues that knowledge and understanding of ICT processes are required, in addition to skills, if pupils are to make effective use of ICT, but many teachers believe that no input is required from teachers during lessons, and that pupils will learn from the computer or from each other.

Webb (2003b) has analysed the ICT curriculum in relation to problem solving, which is a key aspect of ICT. She suggests that two key elements of the content understanding required for ICT-based problem solving are: first, the concepts and techniques of representation of data, knowledge and processes; and secondly, the metaphors and capabilities of types of application software. These may be best addressed by pedagogies based, respectively, on the theory of Anderson *et al.* (1995) and on the minimalism theory of Carroll (1998). These pedagogies need to be developed by teachers and are likely to incorporate carefully designed practical tasks with appropriate scaffolding as well as techniques to develop understanding. Just as in mathematics or science, discussed in the previous sections, children of primary school age are expected to develop knowledge and understanding of mathematical ideas and scientific concepts as well as skills in numeracy and in conducting scientific experiments. This means that in ICT children need to develop understanding of ICT systems and processes as well as skills in their use.

Teachers in the focus group meeting (see Section 6) emphasised the importance of **teaching** ICT skills and understanding at primary level rather than simply expecting pupils to acquire these skills. They believed that there were a wide range of types of ICT use that were valuable for pupils' learning, and they believed in the importance of collaborative work. However studies of existing practice reveal that much teaching is a long way from these ideals. For example a report on a study of 267 primary school children (years 2 and 6) in five schools in South and Mid Wales (Selwyn and Bullon, 2000) showed their use of ICT both in school and at home using a combination of interview and questionnaire data. These data revealed that although the vast majority of children were making some use of computers in school, patterns of sustained and varied engagement with ICT were rare. Mumtaz and Hammond (2002) observed lessons given by nine teachers with Key Stage

2 children in five primary schools, and found that work with word processors was largely individualised and for presentational purposes (mainly typing up texts initially written by hand) and there was little intervention by teachers.

Earlier research by Murray (1992) showed that primary school teachers did not understand the ICT requirements of the National Curriculum and suggested that limited experience, in particular areas of ICT use, is a likely cause of misunderstanding. Most teachers who responded to the questionnaire survey lacked practical experience in the use of turtle graphics, control, simulations and spreadsheets. Until teachers themselves not only have practical competence in using a range of types of ICT but also have an understanding of ICT processes there is little hope of them being able to develop pupils' understanding. It was notable that some teachers in the focus group meeting of the current project placed heavy reliance on pupils coming to their lessons with a high level of ICT skills and understanding, and they expected those pupils who were less skilful to learn from other pupils rather than from the teacher.

5.3.7 ICT in primary humanities

We did not find any research reports of the effects of ICT on teachers' pedagogies in humanities at the primary level, although there are implications for the primary sector from research studies with secondary pupils.

5.3.8 ICT in primary education: conclusions

Most of the research reported here has been in science, mathematics and English, with some evidence about the teaching of ICT. More than a decade ago, primary mathematics and science teachers reported that 'their main goals for using computers were for motivating pupils' interest in assignments and helping them master basic facts and skills. One or two computers in a classroom are often used to remediate deficiencies or as a reward for finishing other work.' (Becker, 1991 p.19) As we can see from the recent studies such as the ImpaCT2 project, this is still happening in many schools over a decade later.

Changing the nature of learning and knowledge to be learned

In spite of the limited ICT access discussed above, there are positive results reported in many of the focused research studies of the uses of ICT. These have shown that not only does ICT constitute a new resource for primary school teachers, it can also change the subject itself as new ways are found of teaching mathematics, science, English and other subjects. In the case of mathematics, a distinction may also be drawn between changing the ways we do mathematics through the use of ICT and the mathematics itself changing as a result of ICT, especially where a constructivist approach is taken (Smith, 1998).

It is not only the mathematics that can change, but the use of ICT is likely to change the practice of teaching. 'As well as serving as a 'lever' through which teachers seek to make established practice more effective, technology appears also to act as a 'fulcrum' for some degree of reorientation of practice and a measured development of teachers' pedagogical thinking.' (Ruthven and Hennessy, 2002, p.85.) Furthermore, in one study 'A lasting impression from the classroom trials is of the quite exceptional power of the medium to support and sustain collaborative learning.' (Hudson, 1997 p.17) But there was a difficulty with the role of the teacher in relation to use of technology. The teacher's role needed to change to that of an orchestrator of the learning process.

Collaborative learning

Another change in primary classroom practice has been the growth in collaborative learning. This may well have been forced on practitioners initially by the shortage of hardware and the need for pupils to share, but it is now recognised as a valuable strategy. For example one study in the United States (Xin, 1999) examined the effects of computer-assisted co-operative learning in Grade 3 mathematics instruction within integrated classrooms for pupils with and without disabilities, and found that the co-operative-learning group had statistically higher achievement than did the whole-class learning group. Similarly, an Australian study (Yelland, 2002) which was designed to examine social-cognitive interactions and learning also reported benefits of collaborative learning. Twenty-eight year 2 children (average age 7 years, 4 months) worked in pairs on tasks in a computer micro world embedded in a mathematics curriculum. Children 'engaged in activities with a high level of

concentration and found them both challenging and fun to complete.’ (Ibid., p.84.) Working with the micro world enabled pairs to ‘engage in critical discussion’ and be able to ‘generate hypotheses and immediately modify strategies and opinions about concept of length.’ (Ibid., p. 85.) Observations supported the hypothesis that the active construction of knowledge in a computer-supported learning context enabled children to engage with powerful ideas and use meta-strategic approaches. Their spontaneous comments and persistence with tasks indicated a high level of interest in and enthusiasm for the tasks in preference to those that traditionally characterise mathematical activity.

Preparing lessons and class ICT activities

One specific finding, which is repeated many times in the research studies which have been conducted in primary schools, is that teachers state that their role in the classroom has changed from a leadership, didactic role to one of ‘facilitator’ and ‘guide’. Many of the studies do not measure the planning and preparation which teachers have to conduct in order to use ICT with confidence and effectiveness themselves. As we have seen earlier in Section 4, teachers’ pedagogical practices do not begin and end with the lesson. There is a noticeable gap in some of the research evidence about how the whole range of pedagogical practices enable teachers to use ICT effectively. Teachers themselves often do not report on the supporting and preparatory work which is part of their pedagogy. In other words, the teacher may take a role of a facilitator, but this role is only during the lesson. The fact that the evidence here shows how much thought and preparation needs to go into planning such lessons and assessing pupils’ learning outcomes shows that the overall role of the teacher is still that of a leader and expert in their curriculum subject.

Listening to pupils

One major change in the pedagogical practices of teachers in this review is that many teachers report interacting with pupils in a different way than in whole-class traditional teaching. It is already part of a primary school teacher’s practice to set the pupils a task and then to walk round helping individual pupils. However, when the pupils are either participating in a whole-class lesson when the teacher is using the electronic whiteboard, or working collaboratively in pairs at a computer, most of the teachers in these research studies report having more time being available to listen to individual pupils. This enables teachers to gain deeper insights into pupils’ understanding than when the teacher is interacting with the class as a whole.

For teachers to benefit from the contributions which ICT can make to pupils’ learning in primary schools they need to have a detailed knowledge and expertise of the ICT media, the representations of knowledge which these can display and the ways in which ICT use might change their pedagogies. From the evidence in the literature, this will require further substantial training for the majority of primary school teachers, not only in how to use a whole range of ICT resources, but also in how to adopt new methods of teaching without discarding their best pedagogical practices regarding the use of more traditional methods which might be used alongside new technologies.

5.4 Pedagogies for different subjects in secondary schools

5.4.1 ICT in secondary education

Two of the fundamental differences between primary and secondary schools are the allocation of ICT resources and the cross-curricular nature of primary education compared with the subject-specific teaching and organisation in secondary schools (Watson, 1993; Cox and Abbott, 2004). As far as ICT is concerned, this has resulted in many primary schools having a small number of computers and perhaps an electronic whiteboard in each classroom, and teachers using ICT in some subjects. This is very different to secondary schools where the majority have networked rooms, and some have ICT departments, and ICT is taught as a discrete subject. Some secondary schools, however, have no ICT department, and ICT is taught solely across the secondary curriculum in other subjects (Beauchamp, 2003). This has implications for teachers’ pedagogies and has been shown to be a key influence of the way primary school teachers have been using ICT. (Watson, 1993; Selwyn and Butler, 2000) In secondary schools there is more focus on ICT within subjects, although the demands of the teachers who are responsible for teaching ICT often limit other teachers’ access to the technology. (Beauchamp, 2003)

5.4.2 ICT in secondary mathematics

There have been both large-scale projects and meta-analyses which provide evidence of a positive effect of ICT on secondary pupils' attainment. An early large-scale project conducted in the USA (Educational Technology Centre, 1990), involved studying the uses of computers and other technologies to improve kindergarten to grade 12 instruction in science, mathematics and computing, in the context of teaching for understanding. This study identified the need for 'taking account of students' prior conceptions', 'linking multiple representations', 'extending the range of manipulatable objects' and 'using software to reveal students' thinking'.

In the project entitled 'Ways Forward with ICT', Moseley *et al.* (1999) identified a key feature of the more effective teachers. This was their use of effective explanations. The researchers emphasised the importance of taking into account teachers' preferences and beliefs about teaching as well as their attitude to ICT. Teachers need to take into account the need for 'a planned match of pedagogy with the identified purpose of ICT activities and learning outcomes' (*Ibid.*, p. 6.) However, reporting for the National Numeracy Strategy, Brown *et al.* (2001) tried to identify any of a large number of factors relating to teachers and pedagogy which might have 'consistent and significant effects on student gains'. No specific relationships were found for any pedagogical practices. Although the research cast doubt on claims that teachers' effectiveness can reliably be assessed by classroom observation, the team did identify 18 characteristics that they felt distinguished most reliably between the most and least effective teachers. For the most effective teachers, these were to:

- challenge pupils to think mathematically
- expose and relate to children's existing knowledge
- develop significant mathematics skills, eg strategies, generalisations
- develop connections between mathematical ideas, and between mathematics and the real world
- stimulate pupils' interest, curiosity and excitement and sustain engagement
- not set artificial ceilings
- permit access to mathematics and tasks for all pupils
- have integrity of mathematics and context
- have consistency between task and objectives
- use symbols, diagrams and apparatus not for window dressing or as objects in themselves, but to communicate, represent and/or provide good models for thinking
- involve a range of modes of expression
- encourage the development of more sophisticated strategies
- focus on mathematics rather than work or getting answers
- allow the sharing of methods and value contributions of children
- show teachers working with children (use of 'we')
- recognise multiple meanings
- focus on reasoning not answers (not 'cued elicitation')
- accept and work with children's errors.

This list was not completely grounded in the data, but the researchers felt satisfied that it did differentiate adequately between the group of teachers with the highest gains and those with the lowest, although they recognised that there were some exceptions in both groups.

Ruthven and Hennessy (2002) analysed the pedagogical ideas underpinning teachers' accounts of the successful use of computer-based tools and resources to support the teaching and learning of mathematics. Mathematics teachers as a group were found to be relatively strongly oriented towards a 'transmission' view of teaching, as opposed to a 'constructivist' one. A list is presented of the advantages (called operational themes) of using ICT in mathematics: ambience enhanced, restraints alleviated, tinkering assisted, motivation improved, engagement intensified, routine facilitated, activity affected, features accentuated, attention raised, ideas established.

In a three-year project in Australia, (Goos *et al.*, 2003) started from the view that little consideration has been given to the pedagogical implications of technology as a mediator of mathematics learning. For them 'technology' includes not only computers and graphics calculators, but also projection devices that allow screen output to be viewed by the whole class. They suggest four

roles for technology in relation to such teaching and learning interactions: master, servant, partner, and extension of self. Their findings suggest that technology can facilitate collaborative enquiry through both small group conversations and whole-class discussions where students use screen projection devices to present their work publicly for critical scrutiny. Their report highlights the 'vital role of the teacher in moving students towards more thoughtful and powerful ways of working with technology.' In particular 'the teacher's actions in orchestrating students' interaction with the task, the technology and their peers proved to be crucial to their success in finding a solution [to a cubic equation].' The teacher's own pedagogical beliefs and values play an important part in influencing the learning opportunities provided by ICT. This is true whether ICT is being used to reinforce existing teaching approaches or as a catalyst which will change the way teachers and students interact with each other and with the tasks.

In an unusual paper, Joy and Garcia (2000) counsel caution when interpreting results of media-comparison studies. Much of the literature purporting to have found no significant difference in learning effectiveness between technology-based and conventional delivery media is largely flawed, they claim. From a random selection of several representative media-comparison studies they derive critical design considerations for those who evaluate or conduct media comparison research. The question for asynchronous learning network (ALN) practitioners ought to be: 'What combination of instructional strategies and delivery media will best produce the desired learning outcome for the intended audience?'

Among smaller studies, Glover and Miller (2001) explore the impact on teaching of the introduction of interactive whiteboard technology into one secondary comprehensive school. They found that ICT can be used as an aid to efficiency, extension or transformation in teaching, and that teachers' attitudes varied between missionaries, tentatives or Luddites. They concluded that problems with the use of ICT and its limited impact on learning and teaching are more likely to occur where teachers fail to appreciate that interactivity requires a new approach to pedagogy. Training and personal development involving coaching and mutually reflective activity is of the greatest help to staff.

Hennessy (2000), working with graphing with palmtops, observed that the main gains were in the motivation of the students. The pedagogical implications were that arduous graph plotting became very simple, giving the teacher more time for other learning activities. However the teachers could not agree that the laptops were better for using spreadsheet programs than the desktops already available to them. Hennessy and Dunham (2002) maintain that ICT itself can play an important role in shaping the mathematical activity.

Connell (1998), exploring a constructivist approach, observed two classes from the same school in a rural school district during a one-year period. Both classes were taught by teachers who agreed to implement technology within their lessons in markedly different fashions. The purpose was to investigate the potential roles which technology might play in enhancing a constructivist approach. One class utilised the computer as a tool for students' mathematics exploration, the other as a presentation tool, more in line with a behaviourist approach. By the end of the research period both classes easily surpassed both state and district achievement goals and had shown a significant improvement from their baseline. More importantly for this study, however, the pupils in the class where technology usage was consciously aligned with the guiding constructivist philosophy showed a marked and consistent increase in performance. There was also a significant improvement relative to the pupils in whose class the technology usage was at odds with the philosophy of the classroom.

Connell (Ibid.) concluded that the technology should be used in a tightly linked fashion and be supportive of the underlying instructional approaches. It should be used as a tool for students to use in creating their own personally meaningful representations. The presence of the computer alone as a delivery system of static expert representations does not guarantee, and indeed may inhibit, the development of student representations.

Edwards (1998) claimed that micro worlds are created to challenge students' understanding, and that users of microworlds must move beyond that which they know, expect and are familiar with.

In a summary of research on Dynamic Geometry Systems (DGS), Jones (2002) reports that 'interacting with DGS can help students to explore, conjecture, construct and explain geometrical relationships. It can even provide them with the basis from which to build deductive proofs. Overall, this research has found that discussions and group work in the classroom are important components.' Also 'the teacher plays a very important role in guiding students to theoretical thinking.' (p.20)

The use of computers to support constructivist pedagogy was also shown to be effective by Dreyfus and Halevi (1991). They showed that the use of computer programs to provide an open learning environment allowed pupils to explore within a framework, and even weak students were able to deal in depth with a difficult topic, given that the teacher was working as a guide. Similarly, Godwin and Beswetherick (2002) have shown, albeit with one pupil, that a mixture of exploration, direction and guidance within a restricted part of a graph-plotting software package can lead to progression and understanding of the quadratic functions being studied. After taking some risks initially, the teacher eventually reflected that some of the tasks could profitably have been more open-ended. On the other hand, Hoyles and Noss (1992), as a result of their studies in Logo-based micro worlds, make a good case for the teacher restricting the software environment within which pupils may explore and within which pupil autonomy and mathematical expression may take place.

Smith (1998) investigated the relationship between computers and views of mathematics from both individual and social constructivist perspectives. He argued that whereas social constructivists are more likely to take the position that computers alter the way we do mathematics, individual constructivists would more likely say that computers change the mathematics that we do. Individual constructivists, by placing mathematics itself within the actions carried out by an individual, provide a theoretical framework that allows for the richness and diversity of student constructions that can expand our understanding of mathematics beyond the bounds of any one particular culture.

In another study (Connell, 1998), two classrooms from the same rural school were used to show that constructivist teaching using the computer for exploration yielded better results than an instructional philosophy. Results have also indicated superiority in children's judgements of time when specially written multimedia software was used (Panagiotakopoulos and Ioannidis, 2002).

Stevenson (2000), after making a comparison of existing pedagogical settings, goes on to highlight the ways in which direct-manipulation environments might be used for teaching and learning, by considering the connections between geometry and the semantic and syntactic structures of Newtonian mechanics.

Sutherland (1993), working in the area of Logo and the concept of variable, draws as her main conclusion that in mathematics education we need to make more explicit the underlying theories influencing our work, because these theories influence both the ways in which we work in the classroom and the ways in which we analyse our data. She quotes Vygotsky (1962) who maintained that 'Practical experience also shows that direct teaching of concepts is impossible and fruitless. A teacher who tries to do this accomplishes nothing but empty verbalism, a parrot-like repetition of words by the child, simulating knowledge of the corresponding concepts but actually covering up a vacuum.' (Ibid., p. 83.)

5.4.3 ICT in secondary English

Much of the empirical evidence in English reports similar uses of ICT to that found at primary level, although the uses made of ICT are more demanding, and English is taught as a separate subject in secondary schools with much less focus on literacy skills. In a study across six curriculum areas, which included English, Hennessy *et al.* (2003) found that the use of the technology was associated with a decrease in direction by the teacher, and an increase in pupil self-regulation and collaboration. One effect of these changes in classroom practice was that teachers felt the need to employ a proactive approach in their teaching and develop more responsive strategies in order to support, guide and facilitate pupils' learning. This also involved monitoring pupils' progress more closely and maintaining a focus on the learning of the subject. Pupils were also encouraged to take

more responsibility for their own learning through increased participation. While an extensive range of successful strategies were employed, many of which built on established practice, the authors concluded that the pedagogy associated with using ICT to support subject teaching and learning was still evolving.

According to some researchers, the use of ICT has the potential to transform English teaching, although the vast changes to pedagogy that this will entail may well be resisted by teachers (Russell 1998). The author describes secondary pupils' experience of writing hypertext⁸ stories over an 18-month period. Stories were written over a period of about three weeks and the pupils were encouraged to write in pairs. Just over half the students supported the use of collaboration in hypertext story writing and all the teachers and the majority of the students supported the multi-linear aspect of hypertext. A few students, however, preferred to write straightforward stories without branching. Students presented their stories to the audience and this was seen as an important way to encourage them to consider the needs of their audiences. Teachers felt that the collaborative pedagogy was encouraging students to think carefully about the meaning of words in their hypertext. It was concluded that non-linear writing requires different teaching practices from a story centred on expectations of closure, and incorporating pictures into text runs contrary to discourse based on words.

5.4.4 ICT in secondary science

Bell and Bell (2003) conducted a search of the education literature to identify articles dealing with the topic of technology in science education from 1994 to 2002. They produced a bibliography of over 200 published articles and book chapters related to applications of technology in kindergarten to grade 12 (primary and secondary) science teaching or in science teacher preparation. Their motivation for this work was a discussion at the National Technology Leadership Retreat 2001 that highlighted the inadequacy, perceived by science educators, of the literature supporting technology in education. From their search, Bell and Bell concluded that part of the reason for this perception is that many teacher educators are unfamiliar with the literature that has been published because it is in journals that are not familiar to most science educators. They have merely listed rather than critiqued all these articles, which are in a range of journals. Some but not all of these articles have been reviewed here, together with others that were not included in the bibliography produced by Bell and Bell.

Simulations

Many studies that address issues of ICT in science education focus on the use of subject-specific software, in particular the use of simulations of experiments that are too difficult, dangerous or time-consuming to perform in the school laboratory. These studies rarely consider pedagogy in detail; in particular they often ignore the role of the teacher and sometimes pay little attention to pupil–pupil interaction. Nevertheless they are reviewed because they often discuss the potential affordances of the software and the effects on learning outcomes, so they do address some aspects of pedagogy.

Computer simulations of experiments are often used in short episodes in existing curricula. For example, Huppert (1998) conducted an experimental study of the effect on students' ability to apply their knowledge of the growth curve of micro-organisms of using computer simulations, integrated as short episodes in the existing biology curricula.

The 10th-grade students studied the topic of the growth curve of micro-organisms over four weeks. For the experimental group the activities included a computer-assisted learning (CAL) simulation episode which enabled students to simulate experiments which investigated the simultaneous impact of three independent variables (temperature, nutrient concentration and the initial number of individuals from which to start a population growth) upon the growth curve of micro-organisms. The description of this project places little focus on the teacher's role but does describe the sequence of learning activities in the experimental group:

⁸ Hypertexts are documents, usually presented by a computer, that contain a web of links to separate but related texts. They express the non-linear structure of ideas.

1. Classroom instruction, in which students learned the characteristics of the micro-organisms and how to grow, sample and count yeast cell cultures through practical work.
2. Use of the software program, student workbook and user manual to carry out activities. The software provided a short self-assessment test which was given at the end of each activity, followed by remedial help.
3. Follow-up paper-based work, involving three articles from youth science journals on the topics of population growth. After reading the articles, the students were required to apply their knowledge of the growth curve pattern obtained from their experiments to other population samples, and hypothesise the impact of external factors on various population growth curves.

These study settings created a collaborative learning atmosphere at the computer stations and permitted cognitive learning and social interactions among the groups. Teachers mentioned that the learning environment that developed in the laboratory of the experimental group enabled students to exchange ideas, compare results and make suggestions to each other, for example what range of temperatures to use in their simulations, and what nutrient concentrations to use. Huppert commented on the way in which the use of a simulation could enhance learning within an existing curriculum:

‘In this study we saw that CAL can be used in short episodes in existing curricula, enabling students to perform at higher cognitive levels, investigating simultaneously the impact of three independent variables in one experiment.’

(Ibid., p. 241.)

The suggestion here is that students are performing at higher cognitive levels for two reasons:

1. They are able to carry out more investigations more quickly and focus on their analysis and hypothesising.
2. Their collaboration enabled students to exchange ideas, compare results, and make suggestions to each other.

Tao and Gunstone (1999) investigated the use of computer simulations integrated into a 10-week physics instruction of a class in a Melbourne high school. The simulations were specifically developed to confront students’ alternative conceptions in mechanics. The classroom study was to investigate whether and how collaborative learning at the computer fosters conceptual change. The programs provided students with many opportunities for co-construction of shared knowledge. During the process, students complemented and built on each other’s ideas and incrementally reached shared understandings. Students’ conversational interactions showed that this led to conceptual change. The focus was on interaction between students and did not address the role of the teacher. Nevertheless the study suggests the desirability of providing opportunities for collaborative learning.

Jimoyiannis and Komis (2001) found that extending theoretical instruction for 15- to 16-year-old students with the use of simulations aimed at the development of functional understanding of the concepts of velocity and acceleration in projectile motions helped the transformation of students’ alternative conceptions. There is little mention of pedagogy in this study, but the implication is that simulation-based activities are slotted in to the existing programme with little change to pedagogy.

Draper (1998) reviewed evaluations of software in use in higher education settings that were associated not just with satisfactory learning but with demonstrable improvements, and concluded that successful approaches can be described by the phrase ‘niche-based success’. Draper argued that the role of simulations of experiments is based on a crucial pedagogical weakness of many practical laboratory experiments. This is not the expense or danger of experiments, but the failure to arrange for students to be intellectually engaged with the conceptual issues, resulting in them being wholly occupied by the mechanical procedure, by following a fixed set of steps, and getting the official ‘result’.

Another type of subject-specific software that has been used frequently in studies described in the literature is that providing simulations or animations of processes that permits pupils to visualise and investigate phenomena that cannot easily be observed. An example in chemistry relates to the

spatial and temporal (dynamic) properties of molecules and how they fit together (such as why snowflakes have a six-fold symmetry, what goes on during melting, and so on), which is often neglected in teaching. Draper (1998) refers to work by Tasker who has developed extensive animations to accurately simulate this invisible domain. This is described as a rare example of a deep pedagogical motivation for using simulation and animation, and pilot trials suggested that it is very powerful in stimulating learners to make new and important connections between fragments of their existing knowledge.

A study using a 'discovery approach' (Barnea and Dori, 1999) showed the value for pupils' achievement of incorporating animations of processes, but did not elucidate further the pedagogy involved. However, a further study reported by Dori and Barak (2001) argued that a combination of physical and virtual modelling supported the development of conceptual understanding by providing visual models. They conducted an experimental study using a new teaching method that combines two types of three-dimensional molecular models: physical (plastic) and virtual (computerised). The research, based on 276 students from nine high schools in Haifa and the northern part of Israel, showed that experimental students gained a better understanding of the model concept and were more capable of defining and implementing new concepts, such as isomerism and functional group. They were better capable of mentally traversing across four understanding levels in chemistry: symbol, macroscopic, microscopic and process. Experimental group students were more capable of applying transformation from two-dimensional representations of molecules, provided by either a symbolic or a structural formula, to three-dimensional representations, to a drawing of a model, and the reverse of this process. The learning unit included theoretical background on organic compounds and enquiry-based learning tasks that involved building and drawing three-dimensional models. The authors found that the enquiry-based learning tasks encouraged understanding of organic compounds and provided students with tools for explaining their answers. An interesting finding was that students at a low academic level in the experimental group expressed their explanation graphically.

Howe and Tolmie (1998) developed software to help collaborating pupils test hypotheses, an activity thought by many to be relevant to conceptual learning. The software addressed hypotheses relating to: (a) the factors which influence the pressure of water, and (b) the factors which influence the formation of shadows. It required collaborating pupils to formulate hypotheses about such factors, decide which factors must be manipulated to check correctness, formulate predictions about outcomes prior to testing, observe the results of tests, and draw conclusions across test series. Pupils were asked to input their decisions at key points as they used the software, and they received prompts whenever they made inappropriate decisions. The prompts became increasingly explicit as inappropriate decisions persisted. The paper describes the use of the software by 9- to 14-year-old pupils, comparing their activity with that of similarly aged pupils who worked with otherwise equivalent software which lacked any prompts. Evidence is presented for the value of prompting, with implications not simply for the use of hypothesis testing as an instructional strategy, but also for the design of computer-based support for other complex and co-ordinated activities.

In summary there is evidence from experimental studies that various aspects of achievement can be improved by integrating simulations into topics that students find conceptually difficult. The simulations are integrated into the existing curriculum and combined with laboratory experiments, theoretical instruction and in some cases exploration of physical models. The activities involving simulations are problem-solving/enquiry tasks set by the teacher in which students interact with each other as well as the teacher. Descriptions of the studies suggest, but generally do not explicitly state, that the student collaboration is an outcome that was encouraged but not specifically designed by the teachers, and that this collaboration may lead to improved attainment. The role of the teacher is not explored fully in most of these studies.

Student research projects

Hollow (2000) presents case studies of student research projects in optical and radio astronomy from schools in Australia and elsewhere, and details both the benefits and problems faced in conducting such projects. The benefits of these types of experience are difficult or even impossible to quantify or describe in terms of students' attainment or achievement in any measurable way. Hollow argues that student research projects provide a valuable opportunity for secondary school students to experience many of the joys and frustrations that make up the intellectual challenge of

science. Use of the internet and remote access telescopes allows students to undertake challenging research and make worthwhile contributions to professional programs. Clear guidelines as to what a student research project involves and requires are crucial for success, and here the internet has a role in supporting communication. The role of teachers in a successful student research project is critical, and again the internet can play a role in supporting networks of teachers.

Wilson (2001) in a brief paper describes how his class of students used a website to find out information about woodlice prior to carrying out practical investigations for GCSE science. The website gave them a greater choice of investigation and therefore supported their planning, so some were able to achieve level 8. It also enabled them to relate to other work in their analysis.

In summary it has long been recognised that student research projects enable students to gain insight into how real science investigations may be conducted. They are difficult for teachers to manage because students and teachers need access to a wide range of information.

Producing multimedia and video

Kafai *et al.* (1997) describe how, in teams, pupils of 10- to 12-year-olds produced a multimedia information source on astronomy. The researchers reported that students had to think about their users and so produced text in their own words. Content screens and animations provided more affordances for understanding than quizzes, which were generally unconnected questions with factual answers and no sequencing. These projects are typically time-consuming; in this case 46 hours over three months.

Michel *et al.* (1999) suggested that the pedagogical value of a student making a video clip is that it allows for the development of powers of observation as well as opening new perspectives for their understanding of science concepts. This is because students need to think about whether or not a video clip is appropriate to explain a concept, and exactly what should be recorded in order to explain that concept. The availability of the technology to make digital video clips gives a teacher the flexibility to demonstrate scientific concepts that would otherwise have to be done as 'live' demonstrations, with all the likely attendant misadventures. Enquiry-based teaching assumes that students are involved in initiating problems to investigate, searching for alternative solutions to the problems, collecting and tabulating data, reporting conclusions, and suggesting new related problems for further investigation. In one example (*Ibid.*), movie clips were produced by a high school biology teacher who produced a CD-ROM full of short clips digitised from tapes made by students during a long-term experiment to grow various plants. The students eventually incorporated the clips into scientific presentations.

Reid *et al.* (2002), in an evaluation of a pilot study of digital video in 50 schools from across the UK, reported that teachers commented that filming 'forces' and editing this into a piece of video helped pupils assimilate scientific concepts more effectively, quickly and substantially than a handout or textbook would have.

Real-time graphing

Barton (1997) reviewed some research on data logging. Three different studies on real-time graphing supported the hypothesis that real-time graphing removes drudgery and saves time, and this was also supported by small-scale studies by Barton himself. Barton argues that the main benefit of the graphing facility of ICT is time saving, and comments on the need for further research into the need for interaction between peers and the intervention of teachers.

Linn and Hsi (2000) found that students are much better at interpreting the findings of their experiments when they use real-time data collection than when they construct their own graphs. Students' understanding of time-dependent graphs is enhanced even in topics not studied. For example, students were better at interpreting graphs of speed over time after studying cooling over time when they used real-time data collection. No similar benefits arose when students used conventional techniques for graphing their data.

Distance education

Scanlon *et al.* (2002) in a review of technology-mediated practical work concluded that collaboration at a distance can work. Their study was focused on higher education where distance education is necessary, but they also reviewed studies at school level. They outline a number of projects across the globe, including five aimed at school level that offer remote experimentation, but comment that

as yet information on most is limited and that the technology involved and the learning experiences that the systems enable is unclear. They comment that these projects will be worth following up as they publish their reports, but it was not possible within the time-scale of this research to do so.

McKinnon and Nolan (2000) discuss distinction courses for secondary-aged gifted and talented students and describe in particular a course on cosmology. This course employs an interactive design model and an extensive communication system in which the concept of 'learning community' largely replaces the concept of 'teacher'. The interactive design model of the course comprises three key design elements: print-based study modules, residential schools and significant others, including the course co-ordinator, research astronomers and cosmologists who provide students with support and guidance, and a communication system for linking the students with the elements and with each other. In the learning community of the cosmology course, with the participants connected electronically, the students play roles principally as learners while significant others, for example, the course co-ordinator and astronomers, play the roles of facilitators of learning, mentors, critical friends, interpreters and discussants. In delivering the cosmology course, the explicit incorporation of the communication system into the program design enabled students to exercise control over and manage their learning, gain the support they required and achieve results that were personally satisfying. Achievements in this context are very much individual and are documented in this paper through vignettes about successful students and how their projects developed. Students achieved work of a very high standard. For example, a 17-year-old student demonstrated the ability to interpret the observations currently being made by researchers at the leading edge of observational astronomy.

A teacher-based case study (Poland *et al.*, 2003) researched the use of a virtual field station for the teaching of an A-level biology topic. Students' fieldwork involved Mediterranean sea turtles. The paper argues that a virtual field centre is an effective substitute for the real thing in terms of the development of student knowledge and understanding for examination purposes. The evaluation revealed no difference between students' achievement with the virtual field centre and with real field studies, but suggested that there was an increase in discussion and peer interaction with the virtual field centre. The relative merits of virtual field study compared with real field study and its associated pedagogies is an area that deserves further investigation. Just as Draper (1998) has argued that the choice between the use of virtual or real laboratories needs to be based on clear learning objectives, the same applies to field studies.

Long-term small-scale innovations

Studies of science education described earlier in this section focus predominantly on how the technology supports and enables learning, and provide relatively little information about the role of the teacher and the nature of interactions between pupils and between the teacher and pupils. Long-term small-scale studies provide much better opportunities for examining these complex issues. For example, the Computer as Learning Partner (CLP) collaboration at the University of California (Linn and Hsi, 2000) is reviewed here in some detail, as it was a longitudinal study. In this study a curriculum and associated pedagogy for a semester-long science course was developed that aimed to integrate appropriate ICT. It is one of very few examples of developments where the use of ICT was planned into a new curriculum and the process and outcomes were researched. The collaboration began in 1984 as a partnership of classroom teachers, cognitive researchers, natural scientists, technology experts, and middle-school students. Initially, students used computers to collect and display the results of their experiments. More recently, students used the internet and networked computers, but they still collected data from experiments using real-time technologies that displayed results in graphs on their screens.

A key belief on which the project was based is that it is advantageous to encourage students to explore many different ideas about any given science topic, while helping them combine and restructure these ideas so they can form a coherent and comprehensive perspective on the problem. Marcia Linn, a founder of the project, stated:

'Supporting this process of making conjectures, gaining new information, and reorganising ideas is the goal of the CLP approach.' (Ibid., p. xxv.)

A typical 56-minute period would start with 5–10 minutes of review in a whole-class discussion, before setting the question for the current investigation. The students would then undertake either real-time or simulated investigations. At the completion of each activity, the teacher encouraged students to share results and come to some consensus on what appropriate principles apply and how those principles relate to real-life experiences. The teacher moved from one pair of students to another, asking questions and probing understanding. The associated classroom research studies used pre-tests and post-tests to measure progress. As the curriculum and pedagogy developed, its effectiveness was measured by comparing the performance of two groups: students using the current version of the curriculum, and students using the previous version.

The curriculum that resulted from this development project involved real-time data collection and simulations. Students could label their graphs completely, and make predictions online rather than on paper. They could compare their online predictions with the outcomes of their experiments. Teachers could store students' writing in an electronic laboratory notebook. Assessments and simulated experiments were designed to focus on personally relevant problems. The assessments revealed that adding simulations to the curriculum helped students integrate their understanding and apply their ideas to a broader range of problems.

The design of the CLP curriculum focused on guiding the process of connecting, linking and reorganising so that students could concentrate on thinking about their experiences in productive ways. The software included checklists for students to help them keep track of their progress in an activity, thereby freeing the teacher from answering questions such as 'What should I do next?' and 'How do I do that?' Graphing software enables pupils to predict outcomes of experiments and then compare these with the results. Note-taking in scientific experiments was facilitated by electronic 'sticky' notes. The software freed up the teacher from answering basic organisational questions and provided time for the teacher to probe understanding.

The software also provided scaffolding for students to write their own principles based on their experimental results, and included a range of different types of visualisation of various processes. The teacher described his role as:

'I'm kind of a catalyst. I try to not take part in the interaction between kids but to throw in some ideas that will stimulate a group discussion or introduce pivotal cases. I probe kids to think. Then I let them take it from there.' (Ibid., p. 132.)

Other long-term studies of the implementation of technology in secondary science classrooms are associated with the Technology-Enhanced Secondary Science Instruction (TESSI) project (Pedretti *et al.*, 1998; Mayer-Smith *et al.*, 2000). The TESSI project started in 1992 and was designed to examine the outcomes of combining the elements of successful scientific instruction with the application of state-of-the-art technology. The teaching and learning in the TESSI project revolved around the use of: (1) software-generated simulations to develop and extend student understanding of physical relationships; (2) student-controlled laser discs, videos and CD-ROMs; (3) microcomputer-based labs using computer-interfaced probes/sensors in laboratory situations to collect and analyze data; (4) digitised video analysed by computer; (5) presentation software to present information and examples; (6) interactive testing programs to assess students' learning; (7) computer applications for the students to process and analyse laboratory data; and (8) software for the teachers to prepare, mark, and analyse tests. Specifically excluded from TESSI are tutorial-type applications. The intention is to enhance the instruction done by the teacher, not to replace it.

Researchers report that students enter the classroom with an evident sense of purpose and set to work immediately. Typically, several different activities are in progress simultaneously. Students can choose to work individually, in small groups or in pairs, on interactive laser discs, computer simulations, microcomputer-based lab activities, and other multimedia activities. These less traditional educational experiences are supplemented by the use of textbooks, laboratories, demonstrations, problem sets and fieldwork.

Another theme that comes through, particularly in teacher-designed innovations, and which was also reiterated in the focus group meeting (see Section 6) is that of using ICT to make learning more interesting and exciting so that pupils are inspired and motivated. Smith (2002) describes how

the use of linked web pages to construct identification keys with year 8 pupils (ages 12–13) can make the topic of taxonomy interesting, where it is often seen as boring and outdated. Pupils developed ICT skills as well as observation skills and understanding of classification and biodiversity. The pupils developed their keys and then tested and evaluated each other's keys. The web-based nature of the keys enabled them to be exchanged via a network. The teacher concluded that this approach promotes a wide range of transferable ICT skills, but applies them in the context of a current problem facing real biologists, so illustrating how computer technology is assisting biodiversity research.

5.4.5 ICT in secondary ICT teaching

Although ICT has, for obvious reasons, been used in the teaching of ICT since the 1960s when the main computer subject in schools was computer science, the types of ICT use and its focus have changed over the last 40 years. In many schools this has resulted in the use of a narrow subset of earlier ICT applications (Beauchamp, 2003). Originally, when IT was introduced as a subject with the first version of the National Curriculum in 1988, there was a stronger focus on programming, with systems design, measurement and control systems and machine code programming. With the spread of computer networks into schools, which has been accompanied by office packages and other generic bundles, teachers have tended to adopt a commercially based set of applications in the ICT curriculum. This has often resulted in the ICT teaching and use in schools veering towards a focus on ICT skills, with a lack of coverage of theory and more advanced systems design until pupils reach A-level. In spite of all the support materials available to teachers, such as the Key Stage 3 scheme of work, there is still a tendency for the majority of ICT teachers to focus on skills rather than on a more intellectual and academic curriculum.

A survey of ICT teachers and co-ordinators conducted in 1999–2000 showed that among the 100 teachers who responded, the type of software most likely to be used more often than once a month was word processing (used more frequently than once a month by over 90 per cent of teachers; Preston *et al.*, 2000). This implies, in ICT teachers, a lack of understanding of the subject and the teaching methods which would enable them to teach ICT more effectively.

One of the uses of ICT which has been reported in the discussion of ICT in science earlier in this report (Section 5.4.3) is computer-based modelling, which offers immense potential for the development of causal, spatial and common-sense reasoning (Mellar *et al.*, 1994). The researchers investigated the uses of both qualitative and quantitative modelling with secondary school pupils using different modelling environments. Part of the work involved studying the use of a computer-based modelling pack in schools. This three-year project involved two teachers from five schools in the first and second phase, working on the development of modelling ideas and evaluating them in their schools. The computer-based modelling pack involved modelling software which would have been familiar to many ICT teachers, such as spreadsheet programs, but it also included educational modelling software which was new to the teachers. In the third year of the project, the modelling pack was evaluated in a wide range of secondary schools around the UK, in IT and other departments.

The results from the computer-based modelling project in schools included the following: 'Change can provide both challenges and threats. At a personal and professional level it can call into question values, beliefs and practices that were previously assumed and accepted by teachers.' (Ibid., p. 210.) 'Broadly speaking, the acceptance and integration into routine classroom practice of the modelling approach adopted by the project depended on the extent to which the teacher agreed with the ideology.' (Ibid., p. 211.) The researchers concluded that 'Computer-based modelling can be an agent for change. Some may adopt the innovation whole-heartedly because it reflects their own educational philosophy, others may reject it...our experience suggests that teachers will engage in an adaptation of the innovation to suit their own circumstances.' (Ibid., p. 213.)

Nearly 10 years on from this project, only a minority of ICT teachers are teaching modelling in schools, apart from the occasional use of a simple spreadsheet (Ofsted, 1997, 2002). This slow uptake of the use of computer-based modelling implies that many ICT teachers need to change their educational beliefs and values in order to be able to use ICT effectively in their teaching.

Cope and Walsh (1990) conducted a review of research publications on the teaching of programming. The main conclusions from this review were that 'programming is not as easy as the early optimistic claims implied and...that programming skills require a much larger time commitment than is currently allotted to them.' (p.126) However, one beneficial effect might be 'the habituation to sustained intellectual activity which may occur in a motivated individual and which may then influence the vigour with which other areas of the curriculum are tackled.'

There are several problems for many ICT teachers, which are not faced by other subject teachers, and which make it difficult for them to take on the use and integration of more diverse ICT applications. First, they often have to do several full-time jobs at once, teaching ICT to all the pupils in the school, training their colleagues how to use ICT in their own subjects, managing a large network, and keeping up with the latest technologies at the same time. The doctoral research of Beauchamp (2003) showed that there are still many schools with over 1,500 students in which there is only one ICT teacher (co-ordinator) with all these responsibilities, compared with as many as seven full-time staff in the mathematics department, who only have the responsibility for teaching their own subject. The research discussed here suggest that there needs to be a major change in teachers' knowledge and philosophy regarding 'what ICT means' if pupils are going to benefit from the full ICT curriculum, and there needs to be a major change in the ICT staffing levels in schools.

5.4.6 ICT in secondary humanities

The use of ICT in the humanities has a history which goes back to the early 1970s with the establishment of the Computers in the Curriculum Project at Chelsea College (now part of King's College London). The project was set up to develop and evaluate educational software for a range of secondary subjects, including history, geography and economics (Watson, 1992). In secondary schools, some teachers were using software in these subjects before many other secondary subjects. However, 30 years later, according to the DfEE survey in 2000 (DfEE, 2000), less than 35 per cent of humanities teachers reported substantial use of ICT in their teaching. Although the uptake of ICT in the humanities has not continued as quickly as one might have expected from its early beginnings, there are some relevant research findings regarding the effects on teachers' pedagogies.

The results of a study investigating the use of computers in historical enquiry (Copeland, 1991) suggested that the use of computers might be beneficial to the success of enquiry teaching. Seven teachers, teaching 20 classes of secondary school students, were observed. All taught the same historical unit, but selected different units to teach. Three of the teachers received training in the methods of enquiry teaching, the other three taught in a traditional way. While the results of the study suggested that the support of computers may be beneficial to the success of enquiry teaching, they indicated that such support may not be sufficient in the absence of sufficient preparation by teachers because '...curriculum materials are not "teacher proof".' (Ibid., p. 452.) Despite this it was found that the presence of computer programs enabled properly prepared teachers to teach in a way they would not have taught otherwise. This result, however, implies that these teachers were unfamiliar with the curriculum development in history over the last 20 years, which has promoted an enquiry approach to learning.

Hennesey *et al.* (2003) investigated teachers' and pupils' changing roles and strategies when using various forms of computer-based ICT to support subject teaching and learning in secondary English, history, geography, science, technology and the classics. Although a relatively small-scale study, 115 teacher researchers participated in this collaborative programme of classroom-based projects involving the development, trialling and refinement of new pedagogical approaches, strategies and activities in these six curriculum areas. Analyses were conducted across the case studies from observations of lessons, interviews with teachers and reports from teachers. In these cases the use of ICT was associated with a decrease in direction from and exposition by the teacher, and a corresponding increase in pupils' self-control and self-regulation, and more collaboration between pupils. As a result of these changes in classroom practice, teachers felt that they needed to employ proactive and responsive strategies in order to: support, guide and facilitate learning; monitor progress and maintain focus on the subject learning; encourage pupils' reflection and analysis; structure activities more carefully and provide more focused tasks; pace lessons; and support learning and revision by making available printed and other written resources. Teachers

encouraged and supported pupils to take a greater degree of responsibility for their own learning through increased participation in the lesson.

While interactions with pupils increased, the mediation of interactions between pupils and the technology was found to be under-developed. As the availability of projection technology becomes more ubiquitous, the authors contended that the pedagogy associated with using ICT to support subject teaching and learning would continue to evolve. The authors also found that in order to make the best use of the software, pupils need to develop new skills in order to carry out critical analysis in history and geography (Hennesey *et al.*, 2003).

The use of multimedia learning environments in secondary geography has been shown to affect the relationships between the teacher and pupil and between pupils (Smeets and Mooij, 1999). Using a quasi-experimental design, pupils were randomly allocated to an experimental multimedia group and a traditional control group. Although no differences were found in gains, results showed that there was a significant increase in student–student and student–teacher interaction during multimedia lessons compared to traditional lessons. However, it should be noted that more academic time was spent in traditional lessons compared with the multimedia lessons. Moreover, academic time on task was found to decrease as the multimedia task evolved to a more open-ended learning environment.

Beishuizen (1992) conducted two experiments to investigate the educational value of a simulation modelling program in geography, which modelled the relationships between erosion and agriculture in a developing country as part of the secondary geography curriculum. The hypothesis was that studying the complex domain through exploration with a simulation program decreases the retention of facts and concepts but increases the performance of problem solving. Two fourth-grade secondary school classes of 20 and 18 students respectively were taught using either traditional teaching methods (control group) or working in a simulation environment (experimental group). The experimental group outperformed the control group in factual knowledge and problem-solving questions. However, a second experiment, which was conducted to control instruction time for both groups and to add a demonstration of the simulation program to the control group, showed that, under these conditions, there were no differences between the two groups in the post-test scores. The author concluded that ‘a structured presentation appears to be as successful as offering a learning environment in which students can explore a domain from several perspectives.’ (Ibid., p. 116.). However, he offers two other explanations which have implications for teaching. ‘In the first place, the model of hunger and erosion may have been too complex to be discovered by mere experimentation. Secondly, it may be argued that students were not prepared to explore the simulation environment in a systematic way.’ (Ibid., p. 117.) The author concluded that more training was needed for the students and for the teacher in how to use the simulation environment to take full advantage of its facilities.

Research conducted by the first ImpactT project (Watson, 1993) has shown that among the teachers using ICT in geography, ‘using a piece of software did not in itself ensure a good learning experience, much depended on the teacher’s aims and objectives and their skills in ensuring these were met.’ (Ibid., p. 95.) The study also showed that ‘the use of simulations enabled pupils to develop a high degree of empathy with the topic under study’ (Ibid., p. 94.)

A more recent study into the use of video conferencing between pupils in a network of schools, in geography, showed that video conferencing was a valuable way of developing communication and social skills, and of overcoming the relative isolation of secondary school pupils in special needs schools (Thorpe, 1998).

The evidence presented here for the use of ICT in humanities teaching supports the evidence obtained in other earlier sections about the importance of the role of the teacher in the success or otherwise of using ICT to enhance the subject. The use of ICT simulations and other multimedia environments has also affected the changing roles of the teacher and learner, with increased interactions between teacher and pupil promoted by the dynamic interaction between pupils and computer.

5.4.7 ICT in other secondary subjects

There are research studies reported in the literature about the effects of ICT on the teaching of art, PE and religious education, but they are very few and provide little new evidence about the effects of ICT use on teachers' pedagogies. There is a need for more research in these areas, especially because of the specialised nature of art and PE. The annual DfES surveys report that the lowest uptake of ICT is in these subjects. For the 2000 survey the percentages of secondary school teachers who reported making substantial use of ICT were 27 per cent for art, 16 per cent for religious education and 1 per cent for PE. However, there have been a few studies which investigated teachers' attitudes towards ICT in these subjects which might shed some light on the slow uptake of ICT. It is understandable that ICT use is particularly low in PE since the curriculum mostly involves physical exercise rather than working in a classroom.

Yaghi (2001) conducted an investigation into the effects of teaching experience on confidence in using computers among teachers when using common software applications. It was aimed at dissecting various dimensions of the relationships between subject matter and the use of technology in education, grounded by the participants' own perception of their confidence in using computers and shedding light on the role of teaching experience. The project surveyed 236 teachers in five Lebanese schools who were teaching specific academic subjects: science, mathematics, language, social studies and arts. All had access to a personal computer at home. The results of the questionnaire survey which measured confidence showed that mathematics teachers had the highest degree of confidence among science, arts, social studies and language teachers. Teachers with longer teaching experience had less confidence in using ICT than more recently qualified teachers. With regard to the use of word processing, spreadsheets and CD-ROMs, language teachers had the lowest confidence in all skills, while science teachers had the highest confidence in word processing, mathematics teachers had the highest confidence in spreadsheets and CD-ROMS, and social studies and arts teachers did not differ significantly from any other group.

Teachers who teach different subjects have different experience and different levels of exposure to computers, and therefore may have not implemented computer technology in the same way. The relatively small number of studies in the teaching of modern foreign languages (Cox and Abbott, 2004; p. 38) implies that language teachers need to increase their level of awareness of technology. Our research has shown that this might be increased through allocating a laptop to each teacher to build confidence, and running professional development workshops among peers to combine younger teachers' computer knowledge with older colleagues' teaching expertise.

5.5 Emerging themes

From the theories and the literature review discussed in the previous section we have identified emerging themes relating to teachers' pedagogies and the use of ICT, which are presented in this main section.

5.5.1 Classroom interactions

Hennesey *et al.* (2003) investigated teachers' and pupils' changing roles and strategies in the context of using various forms of computer-based ICT to support subject teaching and learning at secondary level. One hundred and fifteen teacher researchers participated in a collaborative programme of small-scale classroom-based projects involving the development, evaluation and refinement of new pedagogical approaches, strategies and activities in six curriculum areas. An analysis was conducted across the case study data derived from observations of lessons, follow-up interviews with teachers and teachers' written research reports. It was recognised that it is necessary to develop new skills for pupils in information handling and critical analysis, although the teacher's role in this was not consistently perceived. While interactions with individual pupils and small groups increased and were reportedly successful, mediating interactions between pupils and technology through whole-class interactive teaching, modelling and discussion appeared to be under-developed at present. Use of these strategies is expected to increase as availability of projection technology becomes more widespread, and this would further facilitate the important processes of analysis, reflection and consolidation of subject learning. In sum, an extensive range of successful strategies were employed (many of these building on established practice), yet the pedagogy associated with using ICT to support subject teaching and learning is still evolving.

Crook (1998) reviewed research on collaborative learning in children of primary school age and below. He concluded that there is evidence from experimental studies that peer-based learning improves outcomes in terms of learners' performance, but that ethnographic studies of classroom work revealed that effective collaboration between pupils is rare. Studies of pupils using ICT also suggest that effective collaboration between pupils for learning is not easily achieved. For example, a case study by Kumpulainen and Mutanen (1998) of nine pairs of sixth-grade primary school pupils working collaboratively in a multimedia CD-ROM environment in science suggested that a common educational practice in Finnish classrooms of using multimedia CD-ROMs did not produce effective collaboration between pupils. The pupils worked in an experimental setting on problem-solving tasks that were part of the pupils' science curriculum on the concept of energy. In the study, the pupils' task was to prepare a joint poster of the science topic they were exploring. Specifically, the pupils had 60 minutes to investigate, observe, discuss and reflect their understandings of the science topics in the form of text, pictures, graphs and so on, on a joint poster. However, rather than supporting scientific learning, the pupils' activity focused on the use of the multimedia software, organising and arranging working processes, as well as producing neat poster presentations. The actual collaborative construction of science was hence minimal. Consequently, there was not much evidence to support effective scientific learning having taken place.

Jarvis *et al.* (1997) evaluated the effect of collaboration via email links on the quality of 10- to 11-year-old students' scientific investigative skills in six rural primary schools. The observers found that teachers' lack of confidence in science resulted in them providing limited supervision and guidance, and there were considerable periods of unproductive activity in some schools. Teachers with greater confidence in science tended to monitor the children's activities and intervene more, with the effect of helping the children use their time effectively, and in extending the children's scientific skills beyond the basic ones of observation, measurement and recording. However, teachers who used guided questioning in a science/technological context did not do the same when the children worked with the computer, possibly because of their lack of confidence in ICT.

Successful collaboration, according to Crook, requires explicit orchestration. Crook's review of research on collaboration involving ICT (Crook, 1998) reveals a complex picture in which most research is focused on collaborative learning in adults, rather than young children. Current research focuses on distance collaboration rather than peer interaction around a computer, which has been neglected recently. Software design needs to take more account of classroom practice among young children such as 'turn-taking', for example.

Pedretti *et al.* (1998) reported that it is standard practice in the Technology-Enhanced Secondary Science Instruction (TESSI) classroom for students to work with partners or in small groups, and conversation is an integral part of the learning. Seventy-five per cent of the students discussed how they believed talking with their peers 'helped them to learn better'. When asked to elaborate on how and why conversation between students helped, responses fell into two broad categories. Most of the students emphasised that talk supported deeper learning issues, whereas a small group of students focused on short-term, superficial gains from peer discourse. Students discussed how assuming the role of 'the expert' and explaining something to a classmate helped them to recognise when they were, and were not, clear on a concept.

In the TESSI classroom there was a group of students (9 per cent) that preferred not to work or talk with their peers (Pedretti *et al.*, 1998). The students that liked to operate independently were often high achievers who worked at an accelerated pace. These individuals did not need affirmation or advice from their classmates. When they required information, they chose to go directly to the teacher who they perceived to be the 'final authority'. The lower-achieving students who opted not to work with peers explained that they were uncomfortable and worried that their slower work pace might impede the progress of their friends. They, too, tended to seek assistance from the teacher.

Mayer-Smith *et al.* (2000) reported that teachers in the TESSI classroom facilitated learning by working with small groups of students, directing them to useful resources, and helping with problem-solving activities. Traditional lecture-based teaching diminished substantially, and was replaced by just-in-time mini-lessons. Direct instruction was limited to short introductions to new units, revisiting of concepts that students found challenging, and end-of-unit summaries.

Howe and Tolmie (1998), who developed software to help collaborating pupils test hypotheses, present evidence for the value of prompting. They argue that there are advantages in using computers rather than teachers for support. They report research on university tutorial groups that shows that when teachers are present, the flow of communication is mainly from teacher to student and student to teacher rather than from student to student, thereby limiting collaborative learning between students. They argue that support for learning in collaborative contexts may require behaviours that are difficult for teachers, for example 'contingent support' ie support which allows increasing degrees of freedom after signs of learning and that shows increasing direction upon failure to master. They suggest that contingent support is labour intensive, and when it is provided by parents and teachers it can be less than ideal in terms of systematism. This sort of computer-mediated support is not, however, available in most school software at present, and its design is likely to be difficult, costly and require further research. Indeed the whole issue of support, prompting and scaffolding of learning with ICT is one that merits further research.

5.5.2 Control of the learning

Hennesey *et al.* (2003) found that the use of ICT was associated with a decrease in direction from and exposition by the teacher, and a corresponding increase in pupils' self-control and self-regulation, and more collaboration between pupils. These changes in classroom practice meant that teachers felt they needed to employ proactive and responsive strategies in order to:

- support, guide and facilitate learning
- monitor progress and maintain a focus on subject learning
- encourage pupil reflection and analysis
- structure activities carefully and provide more focused tasks
- pace lessons realistically and
- support learning and revision by making printed and other written resources available.

Simultaneously, teachers strove to encourage and support pupils in taking a greater degree of responsibility for their own learning through increased participation.

There is evidence that TESSI students were grappling with a significant change in the management of their learning (Pedretti *et al.*, 1998), for example:

'With a lot of other classes the teachers tell you exactly what to do and, like in the text book the answers are right there in front of you. With this you got to figure a lot of stuff out on your own which I think is a lot better. It's a lot harder at the beginning to get used to. I was really struggling at the beginning until you know how to figure the stuff out. You get used to thinking that way because ever since you started school the answers are there right for you. You just have to copy them out. You've been taught this way. (Ibid., p. 582.)

Self-pacing was overwhelmingly popular with the students in the TESSI programme. Seventy-four per cent of those interviewed indicated that this was one of the highlights of the instructional design. Students also discussed how the self-pacing aspect of the course required them to monitor their own learning, and contributed to their time-management and organisational skills, fostering a kind of self-regulation and direction extending beyond the immediate use of technologies. However, not every student interviewed in this study spoke favourably about a student-centred classroom. When discussing their instructional preferences, 14 per cent of the students interviewed reported that they liked to learn in a more teacher-centered environment. This group expressed strong opinions about how they learned better when provided with detailed directions and firm deadlines.

Laurillard (1998) reports observations that reveal that learners working on interactive media with no clear narrative structure tend to be unfocused. Teachers need to prepare instructional worksheets or offer supervision, thus imposing some form of organising structure in order to be productive. Thus one of the key benefits of interactive media, ie the greater control it offers learners, becomes pedagogically disadvantageous if it results in mere absence of structure.

5.6 Pedagogical framework

An important part of this study is to develop an emerging taxonomy of different pedagogical practices relating to different types and uses of ICT in order to help inform the relationships

between them. The pedagogical reasoning process provides a model of teachers' decision making in their planning and teaching. In this section, frameworks that have been used for analysing ICT use are briefly reviewed and discussed, and relevant features are combined with aspects of the pedagogical reasoning processes to elucidate a framework from which taxonomy of pedagogical practices relating to ICT use can be developed.

The first Impact Study developed a 10-point scale for recording and analysing the uptake and use of ICT (Cox, 1993). This did not include any measure of the quality of the ICT work of the teachers, but only the frequency and extent of ICT use. Research over a period of years at the Research and Development Center for Teacher Education in Austin, Texas, on the development of a concerns-based adoption model has produced an extensive levels-of-use scale (Loucks *et al.*, 1998). This scale uses various categories of quality of use to record, rate and assess the extent of integration of innovation in teaching. This model includes seven factors: knowledge, acquiring information, sharing, assessing, planning, status reporting, and performing, which are used to categorise the stages in adoption of an innovation by teachers. The model has been used in several studies to characterise the uptake and use of ICT in teaching. For example, Griffin and Christensen (1999) have developed a self-evaluation tool for teachers. Their model identifies IT as one single innovation and does not include any recognition of the range of types of ICT.

Castillo (2003, PhD in progress) has developed a methodology for classifying teachers by level of ICT use according to the range of types of ICT used. This reflects the number of different types of software being used by teachers, but not the quality of the software itself. Criteria for teachers of different subject areas have been devised which are based on questionnaire responses related to the software types being used in subject teaching. These data have been reported by teachers in the Computers in Education questionnaire and in the recommendations provided by the Chilean curriculum specialists regarding the application of ICT in each subject area of the secondary school curriculum.

Early attempts to classify computer use that have been much quoted in the literature include the classification by Taylor (1980) of the role of the computer as Tutor, Tool, and Tutee, and the four paradigms for computer assisted learning of Kemmis *et al.* (1977). These classifications help to define the roles of the computer and the student. More recently, Squires and McDougall (1994) have reviewed approaches to evaluating educational software and have outlined the Perspectives Interactions Paradigm (PIP) (see Figure 5.1) which focuses on evaluating the interactions between three key actors: student(s), teacher and designer (of software). This framework provides a basis for categorising the locus of interactions, but does not address the nature of interactions.

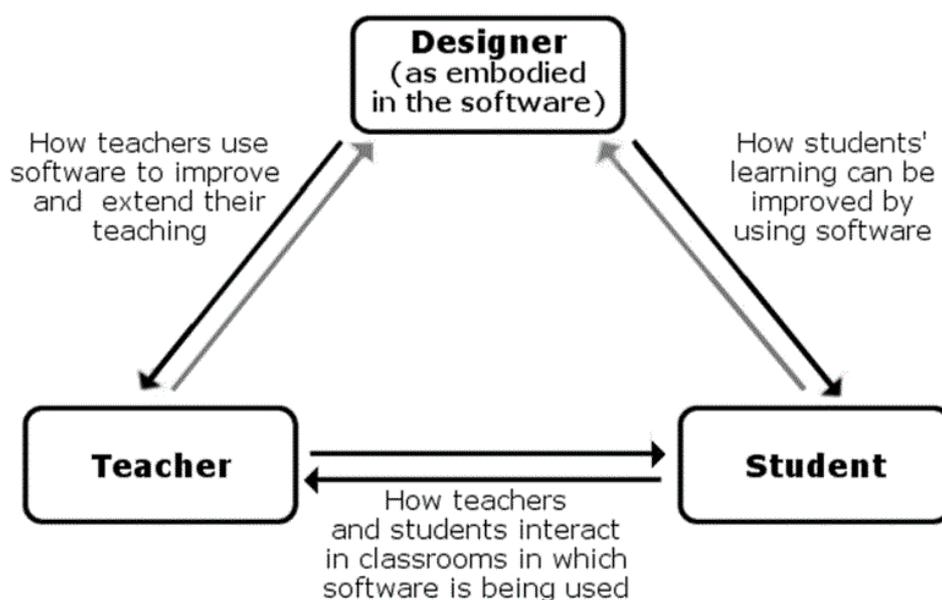


Figure 5.1 – The Perspectives Interactions Paradigm (PIP)

Laurillard *et al.* (2000) have developed a ‘conversational framework’ (see Figure 5.2) from research on student learning that demonstrated the productive and unproductive approaches to learning found in the context of different learning methods. This framework represents the iterative interactions that must take place for conceptual learning to occur. The framework can be applied at any level of description of the learning process. This might be a short dialogue with the teacher explaining something, suggesting a practical example and commenting on the student’s performance of it, or a much more attenuated period covering several encounters, class sessions, assignments and debriefing.

In Figure 5.2, at the discursive level, the model implies that the teacher’s theoretical ideas about their subject lead to specific ways of passing that knowledge (articulation) on to the students. The students provide feedback to the teacher on their understanding, which affects the teacher’s ideas about how to improve their explanations.

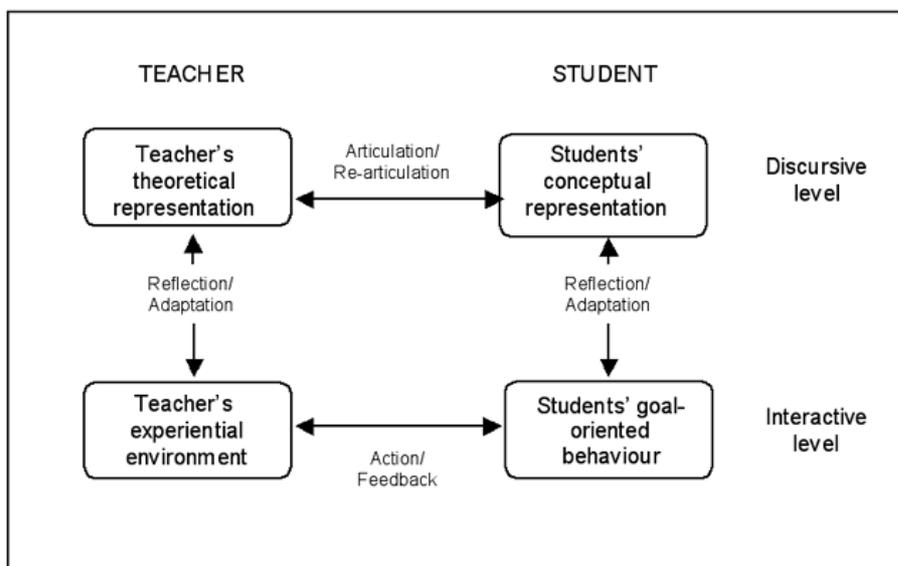


Figure 5.2 – Laurillard’s conversational framework

At the interactive level, teachers are influenced by the discursive interactions with the student, which will in turn influence the learning tasks they present to the student, and so on. These models and others (eg see Twining, 2000) can help teachers and teacher educators acquire a better understanding of the ways in which teachers’ pedagogical practices might be affected by feedback from students and interactions with ICT environments.

In order to provide recommendations which will help teachers use ICT, it is necessary to evaluate in more detail the expectations of the teacher in their planning for **how** they expect ICT to support, enhance or transform, and **how** this is achieved in practice. This means identifying teachers’ perceptions of the features that will provide affordances, and evidence of the affordances in practice and/or perceptions of the pupils. We need to consider not only affordances provided by ICT but also those provided by the teacher, the other students and other resources, the relative balance of these and their inter-relationship, for example, peer support may direct pupils towards features of ICT which may then become affordances. Figure 5.3 illustrates these potential interactions.

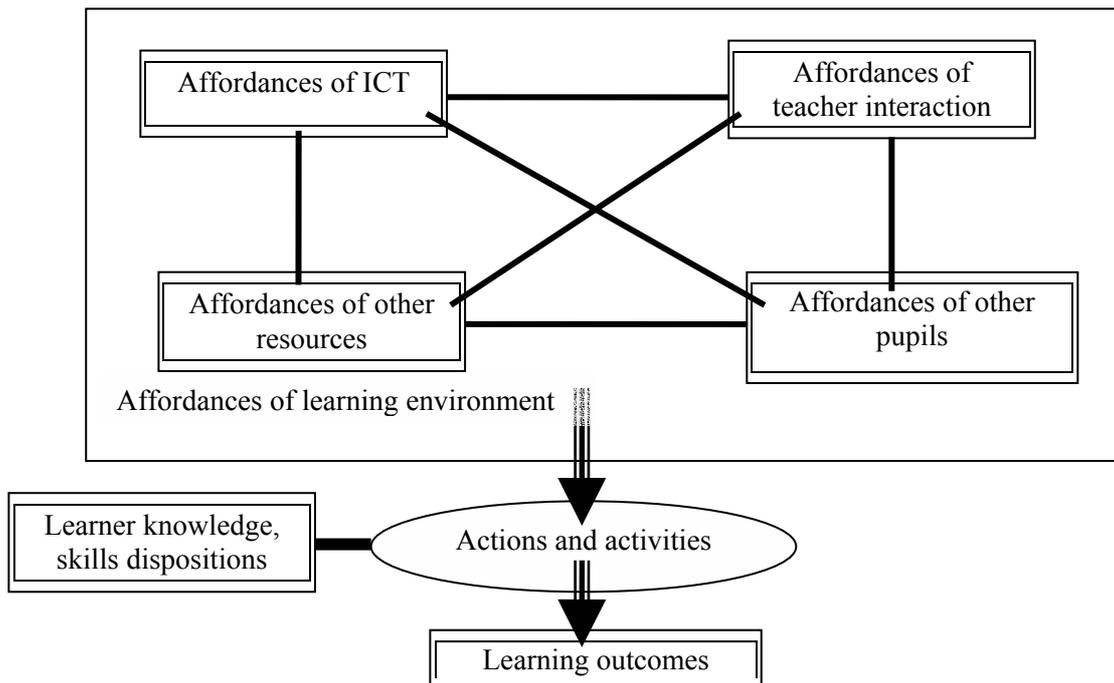


Figure 5.3 – Affordances important to the successful uses of ICT

If we think in terms of affordances, activities and learning outcomes, we can characterise the affordances and the interaction between them. For example if we consider a shared writing activity in which the teacher is modelling how to structure the plot in a story with suggestions and comments from the class, the situation might be as shown in Figure 5.4. The evidence from the literature review shows the very important roles which teachers need to adopt in enabling pupils to engage in challenging ICT-based activities. In this affordance model the influence of the teacher on the learning process is shown through the network of connections and the subsequent influence on learning outcomes. See Table 5.1 for an example.

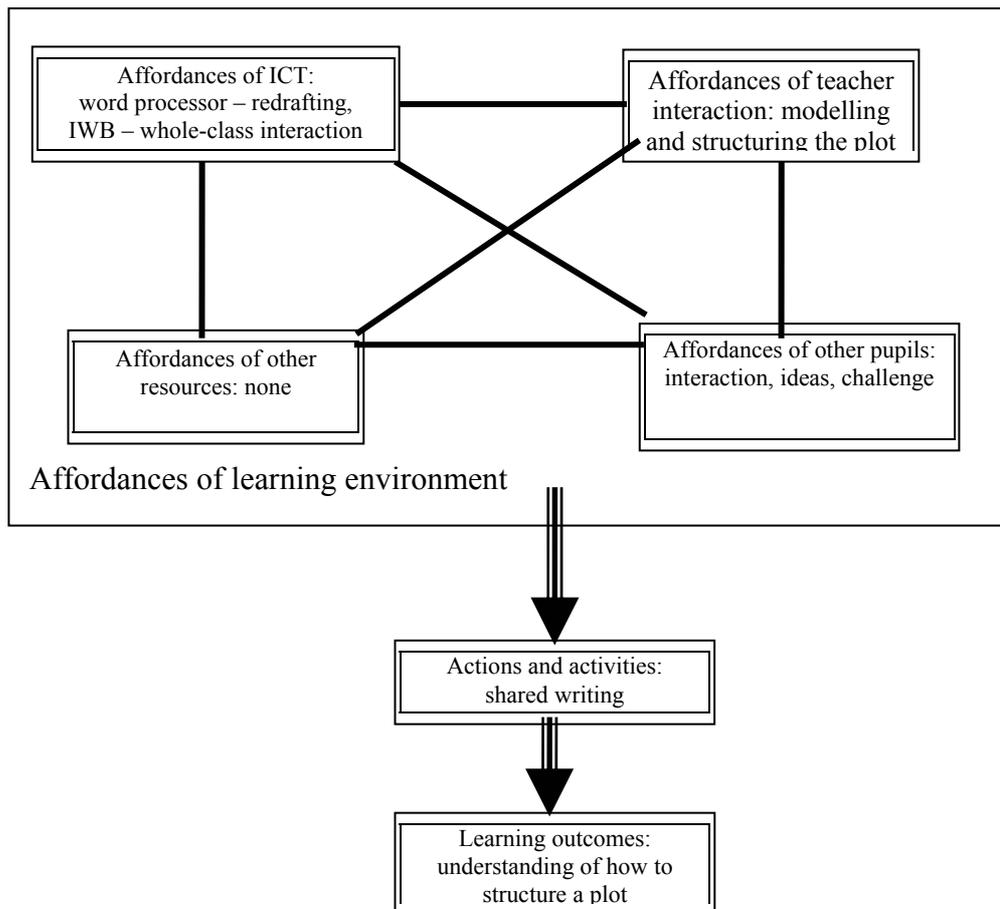


Figure 5.4 – An example of affordances using word processing for redrafting

5.7 Pupils’ beliefs and characteristics

Preceding sections have focused on teachers’ knowledge bases, values, beliefs and reasoning processes, as well as interactions between teachers, pupils and ICT. Teachers’ knowledge bases include knowledge about pupils and how they learn, but there is also a need to examine pupils’ own knowledge, beliefs and capabilities. In particular, in order to understand why particular pedagogical approaches work, it is necessary to examine pupils’ ICT capability, as this will clearly affect the possibilities for using ICT. Our research has shown that ICT capability will also affect pupils’ capability for independent learning, their meta-cognitive skills and perceptions of learning objectives, and their perceptions of the value of ICT for their learning. In addition, Newton and Rogers (2003) have suggested specific ‘application skills’ that pupils need in order to exploit to the full the potential of the software for learning.

Table 5.1 – Application skills for graphing software (Newton and Rogers, 2003)

Graphing tools application skills – the learner as explorer

- Observing graph shape
- Reading values from the graph purposefully
- Describing variables
- Relating variables
- Predicting new data
- Applying mathematical description

The framework that seems to be emerging is a multi-dimensional one that we have attempted to illustrate in Figure 5.5. What this framework means is that teachers' knowledge, beliefs and values will affect their pedagogical reasoning. As we saw earlier from the empirical evidence, if teachers believe that when pupils are using an ICT application they should act mainly as a 'guide' with little intervention, then the pupils' learning progress may be unstructured and less successful than that of a teacher who knows the importance of planning and using a structured activity which will help the pupils learn more effectively. The beliefs that teachers have about the power and scope of ICT, its new modes of knowledge representation and therefore the different ways of pupils' learning, will profoundly affect the affordances controlling the learning actions and activities.

As we can see from Figure 5.5, the pupils' knowledge and beliefs will affect their behaviour in a learning context, which will affect the extent of the affordances which enable them to engage in and benefit from learning. The numerous studies have shown that in addition to the influences shown by the arrows in our framework, the learning context is crucial to the attainment of the pupils and the success of the learning activity. This context includes the resources which might be used alongside ICT activities. It will include the fellow pupils with whom each pupil might interact, and the intervention and direction of the teacher.

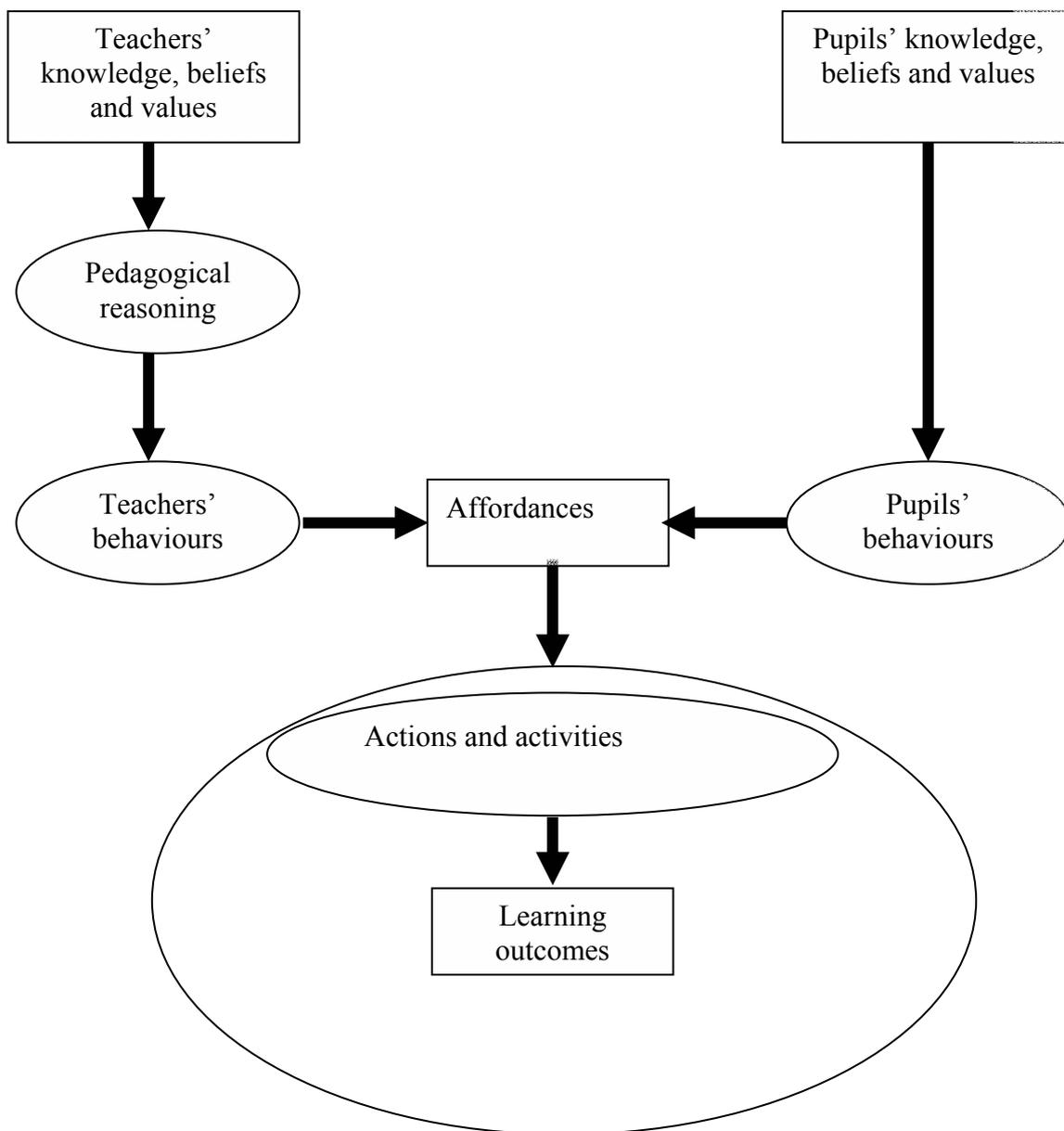


Figure 5.5 – Overview of emerging framework

The theoretical perspectives and the pedagogical frameworks presented above are illustrated and informed by the next section, which presents the evidence from the small case studies in schools.

5.8 Primary school teacher case study results

The project conducted small illuminating case studies in a range of primary and secondary schools which focused on individual teachers. The first part of this section consists of the profiles of the primary school teachers, which were produced from the evidence collected using the methods explained in Section 3.6. These methods included a teacher questionnaire, teacher interviews, class observations, school documents and pupils' work. For details of the ICT skills and experience of each of the teachers and of the background of their schools, see Appendix 6. The names of individuals are fictitious, in order to preserve the anonymity of those involved in the case studies.

5.8.1 Jeffery

5.8.1.1 Lesson using ICT

No lesson was observed with Jeffery because, as headteacher, he was not teaching a class during the researcher's visit. However, during the interview he gave a detailed account of the way learning was organised using drama and video-production for the year 3 and 4 pupils. The literacy hour had been replaced by regular literacy and drama lessons which involved pupils acting out plays and some pupils taking it in turns to take photographs and film the plays. Then, in subsequent lessons, the pupils prepared storyboards of the stories they were going to write based on the plays, using the still shots and video materials to illustrate their stories. In the first lesson the pupils were introduced to the drama project by the teachers and a visiting drama student who spoke Anglo-Saxon. He helped to set up the stage for the play which was based on the legend of the Anglo-Saxon warrior, Beowulf. "We got these great long pieces of pipe insulation, foam insulation, and made spears and swords and then he basically gave them the commands in Saxon. He had this fighting army of pupils at the end of the day and he showed them stage fighting techniques." The drama acted by the pupils was photographed and filmed by other pupils in the class. In the following lessons the pupils created a storyboard, first using still pictures, and then typed up the history of Beowulf, with the pupils on the special needs register being helped by classroom assistants.

The following term, the school decided to adopt a more cross-curricular approach, looking at texts to be used in literacy to help support the history work. Pupils worked on other plays following the approach used in the first term, and "now it is really firmly embedded in the beliefs of the school." Pupils in year 5 are now using the same approach based on the history of Britain since 1945, and "what the children will eventually be doing is putting together a multimedia presentation where they are going to be interviewing people from a period in the 50s, 60s and 70s, talking about fashion, transport, music, politics; all those issues, whatever, and their memories. And of course that person will be filmed. It will be edited, and then put into a presentation along with images that they get from the internet. It will become a visual experience."

5.8.1.2 Pedagogical practices of the teacher regarding ICT

Jeffery's pedagogy had a major influence on the way the literacy hour was interpreted in terms of improving pupils' literacy skills. As headteacher, this influenced the way literacy was taught across the whole school. With over 25 per cent of pupils classed as having special needs, in the past it had been difficult to motivate such pupils to work on their reading and writing. An important aspect of the approach to teaching was to make maximum use of the pupils' oral skills to help them develop their writing and reading skills. This was achieved by encouraging the pupils to act out stories first, taking on the roles of people in the story, for example Anglo-Saxon warriors, and then using new words and expressions they had learned in their writing.

Jeffery had found that pupils were very quick to become blasé about computers, and wanted to 'move on' from just using the PCs for word processing and presentations. "And I think it's important to keep giving them new stimulation and motivation. And I think the nicest thing about the video is even when they've used it, the next time they shoot it, it's different, a different angle, you know, a different way of approaching it." In order to introduce video making to the pupils, the first step was to make still shots with a digital camera and to use these to make a storyboard of their stories. This was then extended to incorporate video material as well.

In using this approach of incorporating a range of ICT activities, Jeffery was changing the way in which literacy was being taught in the school, and adopting new approaches of combining oral communication with visual and written communication. Through the use of ICT he was extending the media through which pupils were learning literacy skills.

5.8.1.3 Evidence of pupils' attainment and motivation

Many of the pupils involved in this activity were originally graded below level 1 in literacy in the National Curriculum. The school assessed the attainment of the pupils through written literacy tests. Examples of individual pupil's work showed an improvement in vocabulary, grammar and coherence when comparing the written work done by pupils before the teaching of literacy through drama and ICT had started, and the work done by the pupils at the end of the term. The attainment of many of the pupils had improved considerably by the end of the term, with extensive interesting stories being produced. An example of a pupil's hand-written work at the beginning of the year is:

'Why frog and snake can't be friends.
Whoch this frog sed snake and snake climde up a big tree.
But then snake climde onto a snapping branch and then snake full and baing snake hit the grand
wen snake fot ip he sied to frog
Why didn't you save me? Sed snake'

At the beginning of the next term this pupil produced the following on a word processor:

Grendel Strikes

'Grendel charged into the door and his eyes glowed with hunger. He ran to the iron gates and ripped them open. Then Grendel scooped up a warrior and ripped him to pieces and sucked every drip of blood form his veins and swallowed him whole...'

Although the teacher provided many such examples of comparisons in pupils' writing, it was not clear at what stage pupils received help from adults or support from spell-checkers and so on.

5.8.2 Adarsh

5.8.2.1 Lesson using ICT

The lesson involved a group of six year 6 pupils studying history and technology. They were preparing a presentation of their knowledge using presentation software, inserting video clips to illustrate their writing. The pupils were using a cluster of five computers. The teacher began with an introduction about the purpose of the lesson, which was to plan a history presentation about the 1950s, 60s and 70s, incorporating six presentation slides, leaving one slide for a video clip. She started by demonstrating to the pupils how to select 'Newfile' and how to access their existing slides. This was followed by a question-and-answer session where the pupils were asked to suggest ideas of how to achieve the task.

The teacher then showed the pupils how to select a 'shimmer' background and the pupils discussed which colours they would use. The teacher then showed them how to copy and paste slides into the presentation, and how to select picture boxes and increase font sizes.

Each pupil was then given a different technology task on a worksheet about history, media, writing and travel. The pupils worked independently creating their presentation, with the teacher moving among them giving advice where necessary. An aspect of their presentations was non-linearity, making it possible to select specific routes through the presentation. For example, "if someone wants to find out about technology, they'll be able to click on 'technology' which will take them to the technology page. Then they can select '50s', '60s', '70s', '80s' and '90s'. They can then click on that and it will take them to the slide that has an interview with somebody talking about technology in the 60s." The pupils worked on the tasks industriously until five minutes before the end of the lesson, when they saved their work to continue and complete in the next lesson with the inserting of the video clip and completing the presentation.

5.8.2.2 Pedagogical practices of the teacher regarding ICT

Adarsh used a combination of presentation slides and video clips for the pupils in their lesson. She believed strongly in the pupils planning an activity first before using the computers. "Out of today's particular lesson I want them to think about how you can move plans for a presentation and put them into reality. So it's linked very strongly to the lesson they did on Monday. I want to make sure that they realise that sometimes if you are going to do something on a computer you need to do it on paper first to help it make sense." Adarsh understood the need for careful planning of the lesson and for preparing the pupils so they could see the ICT activity in the wider context.

The benefit of video-recording interviews was that pupils could review the interviews many times over and focus on what they are listening to. In addition to the relevant information they were collecting, the activity also contributed to their listening and speaking skills.

5.8.2.3 Evidence of pupils' attainment and motivation

The pupils' work was presented through shows of them using presentation software with "few slides but lots of visual effects." Evidence of attainment was obtained through judging the quality of the presentation, which includes how the students relate different types of information, writing with different presentations. "The Labyrinth presentation...shows them using [presentation software] as a very, you know, few slides but lots of visual effects and they used it in that case to demonstrate a poem with noise and shape." The pupils' listening and speaking skills were assessed by judging the quality of their oral as well as written presentations. The pupils' filming and editing skills were also assessed through the quality of their final presentations. According to Adarsh, the level of language, fluency and coherence was higher than for pupils of the same ages in previous years before this ICT activity had been adopted.

5.8.3 Beatrice

5.8.3.1 Lesson using ICT

No lesson was observed with this teacher, as she was not timetabled to teach on the day of the school visit. Instead the observer was shown a video produced by the school of the children using hand-held computers and constructing a database of mini-beasts at a nearby canal. She described a lesson from two years ago in the school's computer suite with 10- to 12-year-old children, which was on the theme of World War II. The lesson was introduced using an interactive whiteboard and projecting the BBC WWII website onto the board. Class discussion took place regarding the kinds of questions that needed to be asked, and then the children were set research tasks, some on the computers and some using a set of resource books and artefacts borrowed from the city museum. Both of the lessons described demonstrated a commitment to the use of ICT in a learning context.

5.8.3.2 Pedagogical practices of teacher regarding ICT

With the children coming from a deprived area there had been behavioural problems in the past with some pupils in book-based lessons. With no tradition of reading in the home, many of the pupils were not very motivated to read in lessons. This was perceived to have changed with the use of ICT. Working in pairs on a computer aided talking and communication and gave the less able pupils pride and confidence in their ability. They found they could use computers as readily as anyone. They were even motivated to read large quantities of textual material on websites. Whereas previously their span of attention would be very limited, the ICT aspect "definitely worked from the point of view of keeping them focused and concentrating." Use of the interactive whiteboard for class discussions had a similar effect. So the concentration of a large number of computers in one room allows a large part of a class, or even a whole class, to access the internet.

Beatrice saw her role when the children were working as moving around the classroom and working with them. "I would go round and check that each group was on task. That they were finding...able to access information they needed, that they were going in the right direction, concentrating on finding the answers or looking at new questions that had arisen or whatever during the time they were working on it. And just reinforcing and keeping things moving. And you might obviously work with particular children that you know needed some extra input there...whatever." So the teacher is seen as the facilitator, reinforcer, helper and provider of stimulus. The lesson began with a whole-class discussion led by the teacher. The pupils then worked independently of the teacher but with a

lot of help and guidance. The advantages Beatrice sees arising directly from the use of ICT are: increased motivation; children always receptive; improved presentation from teacher and pupils; enhancement of teaching materials; raised attainment and confidence; children being very comfortable with the medium and therefore reacting positively.

5.8.3.3 Evidence of pupils' attainment and motivation

The most convincing evidence was seen in the behaviour and enthusiasm of the pupils in this small friendly school. The results for reading, writing and mathematics tests were above the local and national averages and had improved consistently and incrementally since 1998 from 38 per cent to 83.3 per cent in reading, from 29 per cent to 72.2 per cent in writing and from 45 per cent to 83.3 per cent in mathematics. Clearly the school does not claim that all this improvement has been due to the use of ICT, but Beatrice claims that ICT has made her lessons more interesting and diverse, has made them more fun for the pupils, made it easier to control the class, and increased the motivation and presentation skills of pupils. It would appear likely that such factors would have contributed to the success rather than the reverse.

5.8.4 Deborah

5.8.4.1 Lesson using ICT

For this hour-long lesson 27 10- to 11-year-old children were seated either side of an interactive whiteboard. The school had entered a competition, within which they needed to do a presentation for the judges. Part of the presentation was to be given by a pupil using presentation software. The class was, therefore, as the main theme of the lesson, introduced by Deborah to mind-mapping. A brainstorming session was used to elicit what the judges might want to hear, and to start a map of themes and sub-themes. Pupils were asked to type in suggestions and operate the software. They were shown how to use presentation software to display World Wide Web pages, and some pupils were chosen to demonstrate how it was done. A democratic process for choosing the presenter was discussed and implemented in the first stages.

The use of the whiteboard and computer projection enabled a whole class to be involved in developing a presentation which would represent their views. This mixed-ability class joined in what was, at times, an animated discussion on the content, and most were absorbed in the process. It was essentially a planning lesson, which also taught a use of the presentation software that was new to the class. The level of concentration was high for most pupils most of the time. There was better attention to the task than might have been the case with such a class without the use of ICT.

5.8.4.2 Pedagogical practices of teacher regarding ICT

Deborah sees ICT as a catalyst that often stimulates ideas and new ways of doing things in the classroom, which might not even have been done before. She feels that "more and more with ICT we are going to be able to see the pupils setting their own outcomes if we can let go as teachers." She also suggests that the use of ICT has increased her expectations of herself, of the staff and of the pupils, particularly as computers are becoming more reliable. She sees her role as a teacher in a lesson using ICT as a facilitator, a designer and supporter. She believes that to deliver a successful ICT-based lesson a teacher needs to be highly organised, to have done prior research and planning, and to have made sure there is suitable material for pupils of different abilities. Careful management is needed to ensure equal opportunity and access for all children. Although the rewards are evident in increased attainment, motivation, self-confidence and esteem, enthusiasm, social inclusion, citizenship, and collaborative working, the investment in time necessary from the teacher in order to achieve all this is a real problem that needs to be addressed.

5.8.4.3 Evidence of pupils' attainment and motivation

Deborah, who is the headteacher in the school, monitors the attainment tests of all the pupils. As reported in Section 5.8.3.3, by Beatrice, the school pupils' results for reading, writing and mathematics tests were above the local and national averages. Since the school had started using ICT systematically from 1998, these results had improved consistently and incrementally from 38 per cent to 83.3 per cent in reading; from 29 per cent to 72.2 per cent in writing and from 45 per cent to 83.3 per cent in mathematics. Deborah believed that this substantial improvement in results was positively influenced by the use of ICT.

5.8.5 Diana

5.8.5.1 Lesson using ICT

Diana described how she had successfully used a writing program with the reception children, which had enabled them to create their own sentences using predetermined sentence structures and picture clues. Being freed from the laborious task of handwriting had meant that the children were able to construct their own sentences relatively quickly, compared to when using pen and paper. Diana also believed that the children had more ownership of their work as they were making their own decisions about what to write rather than being unduly guided by her.

5.8.5.2 Pedagogical practices of the teacher regarding ICT

Having access to a personal computer had also benefited Diana, as a teacher, in so far as planning her lessons straight on to planning grids made life easier. Also, she was now able to plan tasks for groups of children, which they could then work on independently on a computer.

Diana also perceived that she had become more of a facilitator of learning, for example by helping children to learn to exploit the facilities of the program by “showing them they could put the full stop on and they could hear their sentence and so on...” and encouraging them to focus on thinking about what they wanted to say rather than on the mechanics of writing.

5.8.5.3 Evidence of pupils’ attainment and motivation

The evidence of pupils’ attainment was revealed through the improvement in coherence of the pupils’ sentences and their explanations of their writing and thinking about what they wanted to say. Diana did not use any formal tests.

5.8.6 Annabel

5.8.6.1 Lesson using ICT

Annabel described how using the technology now enabled her to work with the children in a completely different way. The task was a shared writing activity with the objective of writing a letter to the headteacher using persuasive connectives. The class started by brainstorming their ideas, which were written onto an interactive whiteboard. This had several advantages. It enabled the class to be more productive; a task which could have previously taken up to two mornings was completed in less than half an hour. The use of a large screen focused the children’s attention on the task in hand, and everyone had the opportunity to contribute their ideas. The notes were saved so they could be revisited when necessary.

Each child had a copy of the brainstormed ideas which they used to construct the letter, together with the teacher typing the text in for them. Each child then had a copy of this initial version of the typed letter, which they worked on again together, with an emphasis on the use of persuasive connectives, this time with the children making the modifications on their own copy by hand. When all the changes had been agreed, the original text was modified by the teacher and each child was given a printed copy of the final letter. The whole process from start to finish, which could have taken three days to complete, had been achieved in a one-hour lesson. Working together as a class in this way had, according to Annabel, also given the children the opportunity to experience the editing process. According to her, the quality of the finished product was such that the children saw their writing as “...a published piece of work [and] that adds incredible value to what they have written, whereas if it is in long hand and it has got my marks all over it, it reduces the value.”

5.8.6.2 Pedagogical practices of the teacher regarding ICT

This example indicated how the technology had “revolutionised” the way Annabel taught. Whereas before she would have been marking children’s work and checking spellings, she now had taken on the role of facilitator “...watching what they are doing, guiding them in the right direction.” The pupils were also involved in the decision-making processes through the brainstorming sessions involving the whole class.

5.8.6.3 Evidence of pupils' attainment and motivation

The pupils' completion of a long task in a one-hour lesson, when it would have normally taken three days to complete, was evidence of their attainment. The quality of the pupils' final printed products were judged to be superior to their handwritten texts in terms of depth of content as well as legibility of presentation.

5.8.7 Carol

5.8.7.1 Lesson using ICT

Carol wanted to introduce the class to a mathematical game program, based loosely on snakes and ladders, which required the use of arrow keys, thus introducing positional language, such as forwards, backwards, left and right. The program had been loaded onto the classroom's desktop computer and was available for children to explore independently during the free activity time prior to the start of the formal lesson. When the program was introduced to the whole class using a projector to project the program onto the whiteboard, Carol was then able to use the experience of these children to explore the features of the program. She explained that she would have probably found it a difficult task to introduce young children to the concept of what the arrows meant without the program, but "... here (the program) is something that is ready for me." She then used the floor turtle to extend the activity by introducing the notion of orientation and the language of left and right. She had intended that the children should play with the floor turtle first and use some of their prior knowledge about what they had learned previously about batteries and switches to try to solve the problem of getting the equipment to work, before being shown how to operate it. As it was an introductory lesson the children were expected to be learning through 'play'.

This was a class of 28 children, 15 girls and 13 boys. There were two learning support assistants, one of whom supported a special needs child. The children came in from the playground and chose from a number of activities. Three children sat in front of the computer and Carol loaded the 'Ladders' program, which required the user to find the correct number by moving a figure up ladders or down slides. A boy operated the mouse with one of the girls pointing to the target number or indicating the route to take. He was successful with her help and had another go. They then went back to the menu and decided on the 'Dress the Teddies' game. The boy was still operating the mouse although he could not recognise number 5. The same girl temporarily took over in order to locate the correct place. The boy then took over the mouse again. He made several attempts with the girl indicating the correct location and him using the mouse. The boy left and the other girl joined in. The girls tried several programs on the menu. After about 12 minutes the children were called to sit on the carpet while the same software was projected onto the whiteboard from Carol's laptop.

The program menu was projected onto the screen. Carol drew four arrows facing north, south, east and west on the board. The class talked about where they saw arrows in real life. Carol asked the three children who had been using the program to help her find the ladders game from the menu. She explained that they had to make the figure get to the number by moving up and down. She asked the boy who was on the computer how to move 'these arrows'. The pupils then discussed how they could move 'up', 'down', 'left' and 'right'. Carol operated the program while the children sat, very focused, watching the projected image. The teacher talked about the need to make decisions about where to move to next. The children found the correct number and had another go. They then went back to their groups after almost half an hour of very focused whole-class work.

Carol kept a group of average-ability children, two boys and four girls, sitting on the carpet while the rest of the class did other work with the classroom assistants. They sat in a circle with the floor turtle in the middle and talked about the arrows on the floor turtle. Carol asked the girls what to press to turn it on. The children tried pressing the buttons but obtained no response. She asked what they thought the object could do. "Make music?" "I think it's going to move." The teacher told them to look at the wheels and she then asked them what was inside. "Batteries." Carol showed them how to switch the floor turtle on and how to get it to move forwards, a process which included the following: switching on, cancelling memory and pressing twice to go. She then showed them how to move forward by five. The children took turns in moving the floor turtle forwards by a given

amount chosen by the children. They discussed why the floor turtle hit the bookshelf sometimes but not others (the starting position was moved back at one point). The children got very excited and made a tunnel for the floor turtle to move through before it crashed into the bookcase. Carol asked the children if they could work out later that morning how far they could make the floor turtle go before crashing. The group had been working for 30 minutes before stopping for assembly.

5.8.7.2 Pedagogical practices of the teacher regarding ICT

Carol explained that although she introduced this computer program to the whole class she used the technology in a variety of ways, sometimes conducting a whole-class non-computer activity and then using the computer with a group of children. She liked to vary the mode of presentation as she was aware that different children respond better to some learning styles than others. She felt that some liked the whole-class approach while others preferred small-group work. She thought that ICT was particularly good for accommodating different learning styles. She was aware that younger children in particular often learn kinaesthetically so she tried to introduce movement into their learning. She noted how the children using the floor turtle had made tunnels for it to move through and believed that this would help them remember what they had learned. As she explained, learning at this age is "...very hands-on, very active, using the senses, touching, listening to the sounds...and I think that is why ICT works well, because it is visually stimulating and those ways of learning can be well benefited by using ICT with young children."

Carol was aware from her observations that the children co-operated well, talked and supported each other when using computers. They were able to discover how to do things for themselves as they did, for example, when exploring the program initially. It was an "exciting" medium which was "visual" and "stimulating". It rewarded children by giving them instant feedback as to whether they were right or wrong. It enabled children to interact more with their learning and to think more about what they were doing. According to Carol it also made her life easier as a teacher because she did not have to prepare materials because she knew there was software available that met her learning objectives.

Carol believed that her role when using ICT was to teach the children, which she did through demonstration and modelling, and she also "encourage(d), praise(d) and shar(ed) their pleasure at something happening, (and) their excitement." She also said that her teaching had changed so that she now felt sufficiently confident in her own abilities to stand back and observe and not feel that she should always be telling the children what to do. Sometimes a few questions or a little prompt was all that was required.

5.8.7.3 Evidence of pupils' attainment and motivation

Carol had evidence that ICT had had an impact on attainment through the relative progress of the children over the previous year, based on their baseline assessment, in relation to earlier classes.

5.8.8 Louise

5.8.8.1 Lesson using ICT

Louise described how she had used the computer over a series of three literacy lessons. The children had been looking at writing balanced arguments or a piece of persuasive writing, examples of which she had modelled to the children. The children then had a go at writing the introduction or the conclusion for a text themselves. Since the beginning of that term the children had been finding and saving pictures from the internet and saving text and importing it into one document. In this series of lessons the aim was for the children to consolidate this work by tying the two skills together, and to integrate the work in pairs or groups of three. The task was to write either a balanced argument or a piece of persuasive writing on fox hunting. Children worked in mixed-ability pairs. The first lesson, based in the classroom, looked at a series of articles on fox hunting which the children had researched as part of their homework. Louise had then modelled the pros and cons of what a balanced argument and a persuasive piece of writing should contain and then the children planned their work together in note form prior to the computer-based work. In the following lesson the children worked with the laptops in the library where together they reviewed importing a photograph from the internet before starting their writing in small groups. The work was completed

in the following lesson. The whole process was, in Louise's opinion, very time-consuming but 'well worth it'.

5.8.8.2 Pedagogical practices of the teacher regarding ICT

Louise considered that her role during the ICT work was to check that the children were doing what they were supposed to be doing, and to check their work before it was printed. She was not aware of any particular changes in her pedagogy when using ICT. She felt, however, that she needed to be more organised and to think how she could fit ICT into what she was doing, particularly in literacy which is her particular area of expertise. She felt that most children liked using computers and they believed that they did not work hard when using the technology, though this was obviously not the case. She also thought that it broke down academic barriers between children. It had the benefits of being instantaneous and producing a professional end product.

5.8.8.3 Evidence of pupils' attainment and motivation

According to Louise, the interaction between the children during these literacy lessons was enhanced because the children were using a computer. The learning environment was enriched because the feedback the children got was "instant" and "very clear". Because the work the children were doing was carried out using a word processor, they were very focused on what they were writing and were considering ways to improve the content. Without the use of the technology the children would probably have worked on the task on their own, whereas the ICT element "...provided the stimulus for interaction" between children. The children had produced a quality 'published' piece of work which looked professional and which they could be proud of. She also believed that the children would have a better recollection of the processes they had worked through because they had worked together on the task.

Louise felt that, as a teacher, she could see how much children were motivated using the technology and were eager to go on working. Louise concluded that the children had learned something from the lesson because they had all achieved the task. While she was unsure whether the use of computers would raise their SATs results she believed it had "enhanced" their literacy skills and made them want to be writers and to feel in control of their learning.

The school has had consistently good SAT scores at Key Stages 1 and 2 over the past few years.

5.8.9 Mary

5.8.9.1 Lesson using ICT

Mary described how she had used the electronic whiteboard to deliver her ICT lessons. One of the big advantages of using it was that the children could all sit on the carpet and see the screen easily. The pupils were very familiar with word processing, and in this lesson Mary wanted the children to insert a clip art image and use the search tool. She was able to demonstrate the processes involved to the whole class using a whiteboard, and they worked through examples together. Then over the week the children, working in pairs, were able to use the computer to search for their own pictures, enlarge them if necessary, and then insert them into a document and print it off. Having had this experience, during the following week, the children used their knowledge of word processing and inserting clip art to make their own Easter cards.

5.8.9.2 Pedagogical practices of the teacher using ICT

The children were working independently because the teacher saw her role as one of supporting the children, in particular the less able. Mary described how, as she has become more confident with the technology, it has opened up her teaching and encouraged her to experiment and not be afraid of making mistakes.

5.8.9.3 Evidence of pupils' attainment and motivation

Mary found that the children were learning all the time from things that she did with the whiteboard. They were '...constantly, subconsciously watching and learning" from everything that she did. Consequently they were learning not only the educational content, but were also acquiring technical competence. She also found that the computer was a great motivator for children, and noted that they helped and supported each other when working in pairs. The computer also encouraged them

to work independently, for example when choosing the clip art picture. They were very enthusiastic about using the technology and would want to use computers at every opportunity. She had found that the attitude of the children had changed since having the electronic whiteboard, as they were so much more positive and enthusiastic. She also found that she had easy access to so many more resources, and that she was able to cover so much more work with the children.

The class had been quite difficult to manage in reception, but had really improved and this was reflected in their results. Although they had not yet done their SATs, their chances of getting a higher level had increased from year 1 to year 2. This was indicated by changes in their Performance Indicators in Primary Schools (PIPS) results from year 1 to year 2, which indicated that 13 children out of 27 in her class now had a greater chance of gaining a higher level in their SAT scores than was previously predicted. In addition, 13 children were predicted to get a level 3 in mathematics, 16 a level 3 in reading, and 2 in writing. These results were very high for Key Stage 1 and there were only a few children in the class whose predicted levels had not changed, which was impressive given that this was described as a poor class academically when they started school. The change from year 1 to year 2 was described as being quite dramatic. Mary believed that this had resulted in part from her use of the electronic whiteboard, which had dramatically “enhanced their learning” in all areas because of the access it gave them to a wealth of ICT-based materials.

5.8.10 Fiona

5.8.10.1 Lessons using ICT

Fiona described a series of lessons in which the children had used a computer program to present a multimedia presentation. The program was new to her and the children. Working in pairs, the children had a booklet which showed them how to explore the package. In this instance the children had worked in mixed-ability pairs, in order to allow the more able child to assist their less-able partner. The children’s presentations had been a great success and had been valuable in developing their self-esteem.

They then went on to use their knowledge of the software to create a presentation entitled ‘How ancient Greek ideas are used today’, using encyclopaedias, research books, the internet and CD-ROMs to research the topics. This indicated to Fiona whether or not they had retained the skills which were developed in the previous lesson.

5.8.10.2 Pedagogical practices of the teacher regarding ICT

Fiona valued the interactive whiteboard because of the ease with which it enabled her to do things, such as draw a triangle and then discuss it with the whole class. It also provided her with a wealth of teaching materials which cut down on her planning time.

The use of computers had changed her practice in so far as she had less need to photocopy materials for the children. There was also less concern about having adequate materials such as books for all the children, and the use of the electronic whiteboard meant that materials were available to the whole class. The use of the internet also presented her with a wealth of ideas that it would not have been possible to access using other media.

She described how the class had done some shared writing on an introduction to a story where they had pooled ideas which she had written on the interactive whiteboard and had saved for the following day. Areas of this text were then highlighted for the children to develop. So rather than having to photocopy the text for the whole class to work on in pairs, the children had been able to read it as a whole class, then work in groups discussing the text, and then come back, edit and continue to develop the text. One of the advantages of working in this way was the way in which the children were able to develop the text as a whole class. Each child was then able to have an individual copy of the work.

5.8.10.3 Evidence of pupils’ attainment and motivation

Children were said to have had at least two hours per week using a computer either as a discrete subject or through subject areas. She believed that children were much more “enthusiastic” than

they would have been just using books. In her opinion children's skills were being developed every day, which was preparing them for a society where ICT would monopolise their lives.

Fiona had an assessment sheet which she used to record the children's level of competence as indicated in their multimedia presentations. These were classified under five specific learning objectives. All but one child of high or average ability were classified as 'competent' in all areas, and the other child was deemed to be 'competent' in three of the five areas.

5.8.11 Primary school case studies – conclusions

The 10 case studies reported here showed some interesting examples of innovative uses of ICT in primary school classes. There are several common findings as well as individual examples of new pedagogical practices among the 10 teachers. The ways in which these case study data illuminate the findings from the literature review are discussed in more detail in Section 6.

5.8.11.1 Background of the teachers' schools

The schools varied in size and social background, as well as in the types of ICT resources available. One school had a pupil : computer ratio of 3 : 1 in a class, while at the other end of the range there were two to three computers in a class. Many of the teachers had access to an electronic whiteboard, which enabled them to use ICT for whole-class teaching. The schools were all actively supported by the headteacher, and most of the teachers had specific responsibilities for an aspect of primary school teaching, such as being the ICT co-ordinator, the headteacher, deputy headteacher and so on.

5.8.11.2 Teachers' ICT skills and experience

Not all the teachers were experienced in all the aspects of ICT, which one might require to meet the Teacher Training Agency requirements for newly qualified teachers, and some teachers even said that they were unfamiliar with basic aspects of ICT. However, they all expressed confidence in using specific ICT resources in their teaching and believed it to be an important resource for the learning of their pupils. None of them used ICT only occasionally, and it was clear from the interviews and questionnaires that although they did not use a wide variety of ICT applications, they were regular users of some ICT resources.

5.8.11.3 Lesson using ICT

It is clear that from the evidence reported here that primary school teachers mainly focus on specific ICT applications and resources to use regularly in their teaching, but not on many different applications. For example, one teacher used presentation software with an electronic whiteboard with most of her pupils, but never used spreadsheet or other modelling software. Another teacher used word processing, presentation software and interactive video for literacy teaching, but only used spreadsheets once a month. This pattern is repeated among all the teachers reported here. This has implications for further research as well as for future government programmes. For example, what are the reasons for teachers focusing on presentation- and literacy-based ICT activities and not on numeracy, mathematics and science-based activities? This point will be discussed later in the report in Section 6.

Many of the lessons were part of a longer programme of activities with pupils collaborating and preparing joint work with a final product being one of the outcomes. Several of the teachers saw their roles in the lessons as facilitators and advisers rather than as leaders. However, most of the teachers failed to note that their whole planning of the lesson and scheme of work reflected a leadership role in the pupils' learning. Only when the pupils were engaged in a particular ICT task did this role become a more facilitating role, not unlike the role they might take when pupils are reading books.

5.8.11.4 Pedagogical practices of the teacher regarding ICT

The pedagogical practices of the teachers ranged from only small enhancements of practices using more traditional methods to fundamental changes in the philosophy of the teachers in the way they taught their subject and the tasks required of the pupils. On the one hand, a few teachers were mostly replacing the blackboard and chalk with an electronic whiteboard, where the main additional advantage was that they could store their board notes and diagrams and revisit them later in the

same lesson, or a subsequent lesson. They also engaged the pupils more actively in class discussions stimulated by the material displayed on the whiteboard and the possibility of entering new text, pictures and so on. On the other hand, two teachers used the pupils to film drama presentations and interviews and then build storyboards around these, ending with pupils' presentations. This involved a change in the way pupils learned English and literacy, by making much more use of oral and video materials rather than focusing mainly on the written word.

5.8.11.5 Evidence of pupils' attainment and motivation

The different pedagogical practices reported above result in different ways of assessing pupils' attainment. These varied from assessing pupils' final written products, using literacy tests, grading of the quality of the content and so on, to assessing pupils through their presentations. In this case the pupils' knowledge and attainment is measured through their presentation, oral and written skills. Teachers reported an increased motivation of the pupils in many instances. This is hard for teachers to measure further research, in which pupils' motivation is specifically measured, could be conducted.

For further discussion on these issues see Section 6.

5.9 Secondary school teacher case study results

This section consists of the profiles of secondary school teachers which were produced from the evidence collected using the methods explained in Section 3.6. These methods were identical to those used in the primary school case studies, and included a questionnaire for teachers, interviews with teachers, observation of classes, and inspection of school documents and pupils' work. For details of the ICT skills and experience of the teachers in the case studies and of the backgrounds of their schools, see Appendix 7. As with the primary case studies, the names of individuals are fictitious, in order to preserve the anonymity of those who took part in the research.

5.9.1 Adrian

5.9.1.1 Lesson using ICT

Twenty-eight mixed-sex and mixed-ability year 8 pupils worked in a laboratory with 15 bench spaces, each equipped with two flat-screen PCs networked with broadband internet access. As they entered they were asked to pair up with a partner of their choice. After registration Adrian explained the object of the lesson, which was for each pair to produce two presentation slides. These slides were to report on research into an aspect of the solar system, and would then be incorporated into a resource for the whole class.

The pupils worked with total absorption in the task. A list of URLs for useful websites was projected onto the whiteboard and pupils were expected to restrict their searches to these sites. There was clearly co-operation between the members of the group, and also a fair degree of work-based communication between groups.

Once the introduction was complete and tasks had been allocated, Adrian's main task was to move around, stimulating and helping. Most of the dialogue between pupils and teacher was science-based. There were also occasional technical or ICT-related questions. One example was a pupil asking how he could send his presentation screen by email to his partner, sitting at the same bench, so that they could combine two screens for their presentation. All of these queries were dealt with promptly and efficiently, and although there was a constant stream of questions the number was not overwhelming. Most pupils were very skilled at moving between internet sites and the presentation program, and appeared very comfortable with the use of the technology for research and presentation.

As the end of the lesson approached the rate of working increased with an announcement from Adrian that there was 10 minutes to go. Pupils were asked to send their finished work by email to Adrian, and he projected the contents of his email inbox onto the screen. Several arrived complete before the end of the lesson. Those who had not finished their slides were expected to finish them during lunch-time and send an email of the results to Adrian by the end of the day.

In a lesson of just over an hour the whole of the solar system had been researched. In a later lesson each part of the amalgamated slide show was to be presented by the pupils to the rest of the class, with additional points of interest added by Adrian.

5.9.1.2 Pedagogical practices of the teacher regarding ICT

The use of the internet for research, and the subsequent multimedia presentation of the results of the research are central to Adrian's use of ICT in his work. Not only the technology but also the way it is used in the class is important. It begins with Adrian building a list of resources in the form of books and websites that are relevant to a topic being studied. He quoted an example of an earth studies module. He is able, with a top set year 10 group, to divide up the topic and give a section to each group of up to four pupils to research. According to Adrian, they have the necessary research, ICT and presentation skills to teach the other groups in the class about their allocated section. As they typically only have 10 minutes to present their work, this discourages them from cutting and pasting large amounts of irrelevant or incomprehensible text from websites. Within their groups they also have to co-operate and combine their efforts for the finished product. The presentations are then built into future lessons and augmented by Adrian with added information and consolidation tasks.

The pupils “clearly enjoy this way of working and they learn to research selectively, they learn the work more effectively having had to look for and structure the information themselves. They learn to do graphics and animations and very importantly, do this co-operatively in a team situation so they learn teamwork skills as well. Also just to make things different. I think a lot of pupils get complacent, they sit in the lessons, they hear what the teacher’s saying, they do the tasks and they don’t actually get involved in the lesson, through shyness or whatever. I think this gives an opportunity for pupils who are usually sat at the back perhaps or in the middle and not contributing very much to actually get up and have a go and add value to the lessons and help each other learn.”

Adrian believes that the contribution of ICT is to make communication and sharing easier. It also adds an element of fun and the sense of a whole-group experience. With the less able groups there is a need to teach the ICT part of the lesson as well as the science, so it becomes a very different lesson. It also allows the students the means to extend themselves with guidance.

His teaching has changed over the last four years, and whereas he would once have classified his classes as teacher-led, he now feels his lessons have become a lot more interactive. He has also found he is able to put more interesting material into lessons more regularly than previously. However, he thinks also that there is a danger of overload with multimedia presentations across the curriculum.

5.9.1.3 Evidence of pupils’ attainment and motivation

The obvious enthusiasm of the pupils in the lesson observed and the concentration on the task were strong evidence of the value of the involvement of ICT. Examples presented of slides used for a lesson on alkalis and acids also showed evidence of a lively novel approach to science.

Results of a group of lessons by year 10 students on the earth’s structure show a high quality of work, especially if the added value of presentation and reinforcement is taken into account. Marks for attainment for the top set that produced the ICT-aided work reveal that all marks gained for coursework lie in the range A*–B, with the large majority obtaining A* or A grades.

5.9.2 Charlotte

5.9.2.1 The lesson using ICT

The lesson observed provided a good illustration of the difficulties and advantages of using ICT in a lesson. The class was a mixed-ability first year class in this secondary school. The lesson began with registration and the teacher in control at the front of the class with each of the 19 pupils behind an electronic keyboard. The pupils were asked to put on their headphones and switch on the keyboards. While registering the class and talking about the lesson to come, Charlotte sorted out a variety of problems with headphones not working and power supplies not being plugged in. This trouble-shooting continued into the first activity. The department has no technical support.

The lesson proper began with a whole-class activity using software that involved basic practice in recognising notes on the keyboard. The software was operated at the front, first by a boy of lesser ability, who appeared to enjoy the experience, and then by two others in succession who also looked pleased. After 15 minutes the activity moved on to practising the tune of Beethoven’s ‘Ode to Joy’ from the notation.

Having mastered the tune and the fingering, this part of the lesson culminated in a performance without earphones from the whole class in trumpet mode and strings mode, and also played an octave higher with accompaniment from Charlotte. Pupils were assessed on their ability to play the tune correctly with their right hand, and had their assessment sheets marked on achieving this.

The class then split, with half in pairs at five computers working on composing a piece in harmony with repetition, and the other half initially teacher-led at the keyboards composing music with a simple rhythm for a car advertisement. These were both activities that were to continue in the next lesson.

The lesson concluded with a look at what would be expected in the next lesson and a reminder of achievements in the current one. It could be characterised as a very busy lesson, full of a variety of activity and learning. The pupils' interest was maintained throughout and the teacher's communication skills and ability to maintain the working of the technology and treat the pupils all as important individuals were very effective. The technology caused some problems but it enabled the teacher to relinquish control of the delivery of the teaching materials and gave pupils the advantage of keyboard practice and composition practice, facilitated with the possibility of saving their work in electronic form. Most importantly, the level of working was individualised to a very large extent.

ICT was also used to produce booklets of simple music using dedicated music-writing software and to produce the individual assessment sheets for each pupil.

5.9.2.2 Pedagogical practices of the teacher regarding ICT

Charlotte was committed to the use of ICT in the teaching of her subject to the extent that she said she would not want to teach if there were no ICT facilities. Hence her whole pedagogy was built around and supported by the use of ICT. She perceived her teaching to have totally changed. She likened it to having nine other teachers in the classroom who would be helping with the quality she wants from the children. "You are not just asking one person to deliver your curriculum, you're producing it from a lot of different angles."

Charlotte sees her role as being that of a facilitator, although she insists that control is always hers. Initially this means taking a traditional approach with all the class facing her and listening, but later the children take charge of their own learning and up to 10 differentiated tasks may be in progress within the room. She believes in a change of activity every 15 minutes to minimise boredom. The difficulty lies in the first 10 minutes, which, necessarily, may be spent setting the pupils up with individual tasks. To teachers who say they cannot cope with that, she advises looking for an alternative job. Her other important role is that of resident expert who does not know everything, but guarantees to find out within 24 hours.

Her belief in differentiated individualised teaching was underlined by an anecdote regarding her 9-year-old son. He had recently been given a lesson on cutting and pasting in his school. His actual level of expertise was up to building his own website. She regards the teacher who does such a thing to children as either lazy or scared, or both.

Two examples that arose during the day showed initiative on the part of pupils when given responsibility for their own learning. A group of girls were testing each other's ability to recognise the sounds made by musical instruments, using ear-phones and a CD-ROM (and without looking at the computer screen). Another example of initiative was a design for the cover of a written piece of music composition. This had been produced by overlaying computer-produced images and by fading the background layers. In neither case had any instruction or advice been given to proceed in these ways; the initiatives had come from the students themselves.

A lot was achieved in co-operation with the ICT department which provided basic skills training from the second year on, but Charlotte was prepared to teach the pupils anything that was necessary using the interactive whiteboard and demonstrating software. She clearly regarded knowing the software and its capabilities very thoroughly as part of the music teacher's remit. Charlotte does not, however, include the teaching of computer skills as objectives in her lesson plans. She sees the use of software as a means to achieve a musical objective more easily. If a particular computer skill were lacking, she would put it up on the interactive whiteboard and teach it directly so that it could be used immediately.

5.9.2.3 Evidence of pupils' attainment and motivation

On the day of the school visit, the observer inadvertently arrived at the school an hour early. It was therefore possible to see an additional lesson, which happened to be a fifth-year class on the first Monday back in the classroom after a week of examinations. An alert teacher was dealing with a multitude of individual needs and keeping everyone on task at the same time. The observer talked to pupils who were all interested in the task and able to explain it.

Further evidence of the motivation of pupils was exemplified by the story of one girl, related by the head of ICT in the music department staff room: "Colette is a challenging girl, constantly out of school, constantly excluded from school. But when she is in the music department she always does really well. She is motivated, keen to take part and she is just a different pupil when she is here. She is totally different. In discussion to try to analyse why this was the case, the fact that there were other very good teachers in other subjects that were unable to motivate Colette ruled out the teacher factor. The subject when compared with mathematics was thought to play a part. But the most important factor was having an individualised programme for her special needs. This was more easily achieved with the level of ICT provision in the music department."

Again, from the head of ICT: "Obviously that style of giving them something that's more individualised suits them – they are all working at their own pace, and they know what they've to do next. If they've finished something they know what comes next. That kind of course of work seems to be driving up the results, because there's no doubt about it, the music results are excellent just now with that kind of style of teaching." So the combination of individualised teaching with pupils taking more control of their learning and the use of ICT has changed a department. The results three years previously, when Charlotte first joined the staff and ICT was introduced in the music department, were a 43 per cent success rate for the top three GCSE grades and nine failures at A-level. This has been changed to 89 per cent and no failures respectively in last year's examinations. The corresponding figures for the school in mathematics and English GCSE results show declines from 46 per cent to 43 per cent and from 71 per cent to 69 per cent respectively. Since the reorganising of the music curriculum to incorporate ICT, there have not been significant increases in ICT use or any radical changes in pedagogy in either the mathematics or English departments.

5.9.3 Eric

5.9.3.1 Lesson using ICT

There were 27 pupils in the class. They were divided on entry into the room into two parts. Fourteen sat at the computers around the room facing the walls and the remainder sat at the tables in the middle where they could see the interactive whiteboard. All pupils were asked to sit in a boy/girl/boy/girl arrangement. Those at the outside of the room immediately logged on and commenced using Integrated Learning Software (ILS) without any further involvement from Eric. The other half was introduced to various views of a cuboid using the interactive whiteboard to rotate the shape into different positions so the various elevations could be seen. After five minutes mathematics software was then used to present problems on number pyramids that the class had been set for homework. These were worked through and further problems presented, this time involving forming equations to find a missing number. These were also worked through on the whiteboard with a pupil operating it on instruction from the teacher. A similar example was then given for the pupils to work out for themselves using the same procedure. More examples were given for homework. The whole class then changed over with the other half engaging with the ILS and an almost identical lesson at the whiteboard for the other half. The only change of slight significance was the viewing of more complex 3D shapes in the first five-minute section of the session.

The mathematics program was available for pupils to use in their own time during the school day.

5.9.3.2 Pedagogical practices of the teacher regarding ICT

For Eric, the use of ICT in his lesson allows the pupils to be exposed to a diverse range of stimuli. In the use of the interactive whiteboard he teaches largely in a whole-class mode with everyone focused on the teacher. Any discussion is channelled through him. The pupils may, one at a time, be invited to give an opinion or enter a number on the screen, but the whole process is moderated by the teacher. Unlike some other teachers, Eric's basic pedagogy has not changed. He maintains control with a whole-class teaching style. The main difference ICT has made is to enhance his lessons with an audio-visual element, sometimes of a cinematic quality that gives the lessons more variety and maintains the class's interest. He is also able to project onto the whiteboard, and to explain to the whole class, work using other computer programs. Essentially the technology has

fitted in to enhance an existing pedagogy rather than act as an agent for change. The amount of interaction between pupils has not changed significantly, and interaction between pupils and teacher may be direct or mediated through the interactive whiteboard.

One quite radical change that ICT had brought was the opportunity for pupils to access the homework from home via the school's intranet. Some of this homework had randomised content to ensure it was undertaken independently.

The pupils using the ILS were totally absorbed in their work for the half of the lesson when they were engaged with it.

5.9.3.3 Evidence of pupils' attainment and motivation

The pupils were clearly fascinated by the technology, both while working with the ILS and during the ICT input during the taught lesson.

The ILS print-outs indicate progress by pupils as they advance through the program, and suggest learning gains. Class lists for year 7 show added achievement in mathematics since Key Stage 2 and almost all children achieving grade As. The school's key stage test results and GCSE results both generally and in mathematics are consistently substantially above the national average. Eric is clear that any gain in attainment due to ICT use is difficult to measure. According to Eric, there are clear gains in the pupils' attainment through "enjoyment of mathematics; the ability to visualise mathematics rather than see it as a set of rules; the stimulation they receive in the lesson; and the quality of the materials they use. It is easier to control the class and get them learning the things you want."

5.9.4 Frank

5.9.4.1 Lesson using ICT

Frank taught a lesson on magnetism and electricity in a traditional laboratory setting. There were 24 year 7 pupils in the top-set class. Pupils sat behind four heavy wooden benches which stretched across the full width of the laboratory. There was a demonstration bench at the front, alongside which a whiteboard with computer projector was set up temporarily. After homework had been discussed and magnetism terms revised, a CD animation was shown which depicted SS and SN poles and their magnetic fields. Magnets, iron filings, compass points and so on were given out, and pupils worked in twos and threes on the experiment to identify the lines of force in the magnetic field. Pupils then wrote up the experiment and gathered at the front of the class for a demonstration of the magnetic field round a wire carrying a current. This did not work very well and neither did another experiment which should have simulated a simple electric motor. The lesson finished with a quiz for about 15 minutes using software on the interactive whiteboard with lots of enthusiastic shouting from the pupils and from Frank. The class left after quiet had been restored. This was a traditional lesson in which ICT was used in a supporting role in order to demonstrate lines of force on a screen and then later to present multiple choice questions in the guise of a quiz for the purpose of revision and reinforcement at the end of the lesson.

5.9.4.2 Pedagogical practices of the teacher regarding ICT

Frank has clearly absorbed the use of ICT as a teaching aid which has hardly changed his teaching. He expressed a liking for the old-style laboratory in which he works, and explained the introduction of ICT thus: "When I started teaching I had a chalk and blackboard. I wouldn't say after they [installed] the whiteboard I became a different teacher. And now with the interactive board it doesn't make me an even better teacher or a worse teacher. It's just a tool like any other tools to help me." He sees the benefits of using ICT as speeding things up, allowing a third dimension to be shown, such as animations of atoms and electrons, or the solar system rotating. The use of the interactive board is still an occasional event for Frank and his classes. It is wheeled in for a limited number of lessons. He would like to have it permanently installed in the laboratory. Frank describes a year 10 lesson in which he used a whiteboard demonstration to simulate a rate of reaction experiment from which data on the rate of reaction with different strengths of acids were collected. Without ICT, the experiment might have taken some weeks. The data handling was done on networked laptops, but the networking failed to work properly and students ended up using them as

stand-alone computers. They used spreadsheet software and were expected to convert the data into graphs and draw conclusions. Frank suggested that the majority of the students preferred to draw their graphs with pencil and paper. He admits that he is unable to use the spreadsheet program himself to find the equation of the line and its gradient. He sees no problem with this and takes no responsibility for the ICT skills his students need any more than he takes responsibility for their mathematical skills. He sees the ICT use as just another tool and one which may or may not be used with no disadvantage. In fact Frank sees a danger, if students come to rely on using software, that they will lose the basic skill of drawing a graph for themselves. He sees a parallel with over-reliance on a calculator for calculations.

5.9.4.3 Evidence of pupils' attainment and motivation

Five or more GCSE passes at grades A*–C were achieved by 13 per cent of students in 1991 and by 73 per cent in 2001. During this time though there were many initiatives designed to improve the school's performance, and the introduction of ICT was only one of them, although it is claimed that ICT has played an important part in the development of the college and has been a powerful motivating force for learning. The school feels that one of the great values of computers is that they allow children to work without the interference of adults, which can have a negative effect. "We have now reached the point where pedagogy is being radically affected and demands for changes to teaching spaces are becoming more common." (Green, 2002.)

5.9.5 Gwyneth

5.9.5.1 Lesson using ICT

Gwyneth taught a lesson with a year 10 mixed-ability option class on stakeholders in businesses. She established control initially without the use of computers and led a revision session on all the stakeholders the class could identify from a previous lesson. She also asked the pupils to define the term 'stakeholder'. There was then a discussion of the targets that needed to be met to achieve certain grades in the pupils' coursework. This lasted a brisk 13 minutes. Students then began applying their knowledge to the particular businesses which they had chosen to study. For the next half-hour the students were busy researching information on their chosen businesses and setting up reports on stakeholders. They had access to an interactive business studies CD-ROM and an internet connection. The class was then brought together for exactly five minutes to understand the importance of different stakeholders in different types of business and to be encouraged to think about and prioritise the list of stakeholders for their particular businesses. They then continued to work on their portfolios and eventually logged off. The lesson was reviewed and Gwyneth reiterated the message that they had just one more lesson and piece of homework on the topic, and then the work must be handed in. This was a lesson in which the use of ICT was crucial to the whole process. The students were very much at home with the technology and were engaged and on task, with motivation and enthusiasm throughout the lesson.

5.9.5.2 Pedagogical practices of the teacher regarding ICT

Everything the pupils do is on the computer, including all coursework and homework. It is very rare that they write on paper. It is not required, but Gwyneth expects it of them because they find it easy and because they are able to draft, edit and redraft their work. Her lessons usually begin with five or 10 minutes' talk about the subject area of the lesson, then they go on to 'the package'. This is a CD-ROM designed specifically for vocational GCSE, supplemented with pages from a textbook. Typically students will work between the package and their portfolios, perhaps spending up to 20 minutes on the package and then turning to writing something. Gwyneth sees her role as that of facilitator. "I don't teach except for five or 10 minutes, then the package takes over." It gives her time to talk to the students who are having problems, and to give feedback on pieces of work they have produced. She says the students are glued to it from the moment they begin. They put on the earphones and work alone. Interaction between pupils comes at the application stage when they are writing their coursework portfolios. These count for 70 per cent of the examination. Examiners encourage them to have individual case studies of firms so there is little room for collaborative work. If help is needed with software, it is given on a one-to-one basis as most students will have the necessary ICT skills from earlier ICT lessons taught across the curriculum.

ICT has changed teaching because this amount of assessed coursework could never have been achieved before ICT came along. Gwyneth feels she knows her students better as individuals as a result of the use of ICT. It gives her the time to talk to them all individually rather than just teach the theory from the front. Students have wider access to information from real companies than before. Websites have given them more access to information about companies than would ever have been available in the past. A lot, therefore, would have been studied as theory and learned. A lot of what they now do has the look of computer games and engages their attention more readily than a teacher could have done in the past. She feels it improves attainment, especially that of boys.

5.9.5.3 Evidence of pupils' attainment and motivation

Gwyneth as a gut reaction that the use of ICT in every lesson and the students' interest in the coursework and their absorption in the work during lessons contributes to the higher standards they reach in business studies compared with other subjects. No other subject has such high marks, and no other subject uses ICT in every lesson. This is impossible to prove without a control group, but the results are impressive; 100 per cent passes in year 13 with consistently high added value on the basis of ALIS⁹ scores. Similarly, at year 10, 26 out of the 47 candidates achieved one or two grades higher than their English performance, and the remainder equalled it. No pupils' grades were unclassified. In business studies the A*– C performance was virtually 100 per cent despite many D/E predictions. The exceptions were school refusers who had not done the work.

5.9.6 Henry

5.9.6.1 Lesson using ICT

The lesson Henry taught was with one of two year 10 groups that had been identified by senior management as under-achievers who might benefit from a special course with an alternative curriculum from that given to the rest of the year group. This special course included GCSE leisure and tourism, to a large extent because the course is very much computer-based and it was thought that this might appeal to the pupils concerned and be something of a motivating influence. It was also expected that they would learn enough in this course to obtain a key ICT skills qualification too.

The lesson was based on a software package which is personalised for each pupil. It contains a work scheme, which they were able to follow, complete with keys into relevant websites. Pupils were able to work independently and at their own depth. The intention was for them to produce individual pieces of work, but inevitably there was a lot of pupil interaction within the class.

The pupils were engaged on researching and executing four tasks, which involved: producing a leaflet for a national park; producing a parents' guide for a school visit to an historic building; producing an information sheet for an important national UK sporting event, and producing a tourist guide for two places of historic interest in the UK for a party of middle-aged American tourists. This was designed to occupy them for five hours plus homework.

They were a lively group of 16 students, and the lesson was the last of the afternoon.

For the vast majority of the time the pupils were on task and making some effort to do the research. They had not had an exercise before that required them to find the website from which they would obtain the information they needed. Previously they had always been guided to the place where they would find the information. So this was a real learning situation. They were quite motivated and clearly found a sense of achievement when they found a National Park website giving them information they could use.

Some managed to begin the design of their leaflets. There was no attempt to engage the whole class for teaching from the front, and the pupils were therefore engaged on their individual tasks throughout the lesson. They were boisterous but occupied usefully. The teacher's role throughout was to visit individuals and give them help and encouragement.

⁹ ALIS is the A-Level Information Service, a service provided by the DfES, which allows for the prediction and analysis of A-level scores.

5.9.6.2 *Pedagogical practices of the teacher regarding ICT*

ICT is used here to encourage and motivate a very difficult class to achieve some success and feel a sense of achievement. The lesson worked quite well, particularly for such a large class and at the end of a warm sunny day. The ICT was essential to the course, both in the design of tasks set and in the motivational sense. The research would be difficult and lengthy without the internet capability, and the production and design of leaflets and brochures would also be quite difficult and less satisfactory without the use of computer software.

The effect was to give the students more responsibility for their own work and for them to take ownership of what they were doing. The teacher's task during the lesson became one of organisation, explanation, encouragement and guidance, pointing them in the right direction. Henry relates that when he first started teaching with a blackboard and a piece of chalk he would perhaps stand in front of a class and give out instructions, and it was very much teacher-led. He feels that the way he is working at the moment is as far away from that as it has ever been in the 30 years that he has been teaching.

Henry believes that the value of using ICT lies in the motivational aspect and the presentational capability, which gives even the least able pupils a pride in the finished product. He is convinced that some of the less able are actually achieving what they are capable of, whereas in the past they would have been switched off by their obvious failures. The students are actually enjoying their work.

5.9.6.3 *Evidence of pupils' attainment and motivation*

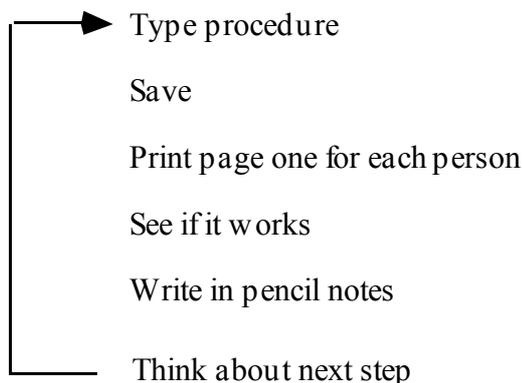
The use of ICT in every lesson and the students' interest in the coursework and their absorption in the work during lessons contributes to the higher standards they reach in leisure and tourism compared with other subjects. Examination results at the end of years 11 and 13 show results at worst on a par with expected grades, but in many cases far higher grades are obtained, some spectacularly higher, than would be expected from students with weak academic predictions.

5.9.7 Hazel

5.9.7.1 *Lesson using ICT*

Hazel talked about the control lesson she would be teaching with a group of year 9 pupils. They had to design and write a program using input and output devices to control a system. She believed that a particular benefit of the control activity was that it involved problem solving and encouraged logical thinking, but in an environment in which pupils received instant feedback when mistakes occurred, forcing them to rethink their reasoning. Print-outs were taken of their work at every stage, thus making their thinking visible, not only to them but also to her. The activity really stretched the pupils as they had to begin by thinking what they wanted their model to do and then put their ideas into practice, which involved a "steep learning curve".

Hazel was observed teaching the second half of the hour-long control lesson described above. It was the second lesson in a series of six lessons. The 12 pupils were working in pairs, each at one computer with the two teachers moving between the groups helping to solve difficulties as they arose. Instructions to guide their thinking were written on the whiteboard:



To include:

- sensors to detect changes in temperature
- sensors to detect whether a window has been opened
- an alarm system
- an alarm button to set off the alarm immediately
- an on–off button to switch on the alarm.

Two girls were working together to complete the following task: ‘Design a control system to detect a system for a flower farm that will open the ventilator when it gets too warm in the glasshouse and close windows when it becomes cooler.’

They had a Lego model of a greenhouse and a control box. One girl keyed the commands into the computer while the other girl copied the commands onto paper:

Procedure

```
start  
talkto “tempa on  
waituntil [tempa>35]  
talkto“anglea on
```

Hazel stopped the class and reminded them to look at the notes from the first lesson about waiting for the temperature to reach a certain level. The girls were unsure whether or not they needed to write a separate procedure to detect whether the windows were open. The girls explained their problem to the teacher who told them that they did not need to write a separate procedure. One girl added ‘talkto “motora on’ to the procedure and the teacher asked her what else she needed to add. The girl replied “end”. They were then told to print out what they had done and to try their procedure out. The teacher asked them how they would do this and the girls explained that they had to type the program name at the start. One of them then typed in ‘to flowerfarm’.

The girls then wanted to change the temperature, but again were unsure of how to do this. Hazel told them to look at what they had done last week and asked them whether changing the temperature would be an output or input to which they reply “input”. The girls tried the program out, printed out the instructions (program sequence) and then modified it, adding 1 to the temperature and 5 to the angle before the lesson ended.

Throughout the lesson the two teachers moved between the groups responding to their queries, by asking them to explain what they were trying to do, then asking them to think how they might achieve the objective, referring them back to theoretical work from an earlier lesson. Print-outs of their work at different stages provided the pupils with a running record of their thinking, which they would annotate for homework.

5.9.7.2 Pedagogical practices of the teacher regarding ICT

Hazel said that she saw her role as mainly a 'facilitator' managing the learning environment, ensuring that pupils discussed and worked things out together rather than one taking the lead. As she explained "we go round and we are listening to them (the children) and trying to develop their thinking skills by doing this, you know sort of typical questions, why, how, what, where, when? asking the pupils to talk through problems and solve them through questioning and answering."

5.9.7.3 Evidence of pupils' attainment and motivation

ICT is taught to all children up to the end of year 11. All children sit a GCSE in year 10, and although the aim is for all pupils to achieve an A* grade, most pupils achieve a top B on average, with, according to 2001-02 results, 43 per cent gaining an A or A*. This is an improvement on earlier years in the school's ICT results.

5.9.7.4 Future developments

Hazel was aware that the future development of the technology across the school was constrained in a number of ways. Although time to develop new ways of working with the technology within subject areas was regarded as a major inhibiting factor, every teacher in each faculty had produced at least one piece of work which developed ICT in a new way as part of their New Opportunities Fund (NOF) training. Money was also seen as an inhibiting factor, particularly in terms of hardware provision, although there were plans to provide a network and internet point in every classroom. It was intended to provide each faculty with a data projector, with two additional ones to be used across the school, and an interactive whiteboard, although Hazel was not convinced that there was sufficient expertise throughout the school to justify a whiteboard in every classroom.

5.9.8 Lorna

5.9.8.1 Lesson using ICT

The use of ICT was not regarded as a bolt-on activity, but was integral to a series of lessons. As there were no computers within the department, the computer suite had to be booked. Initially the pupils would prepare for the computer-based work within the language department classroom, developing materials orally. Lorna believed that it was important that any computer-based lesson should not be focused on one activity. Typically a variety of software programs would be used to develop a range of language skills within the lesson. For instance, she described a lesson with year 10 on the future tense which used a cloze text exercise, a Scrabble-type activity, code breaking and prediction exercises, and also required pupils to produce a piece of free text themselves. Pupils would often work together and discuss answers. ICT in this subject was not used as an introduction to the language but as a means of "development and consolidation".

Even within a selective school, pupils differ in their abilities and aptitudes and Lorna believed that ICT catered for the differences in pupils' aptitude and the different ways they learn in terms of visual, aural and kinaesthetic. It brought immediacy to learning that pupils of today, with experience of using computers at home, have come to expect.

5.9.8.2 Pedagogical practices of the teacher regarding ICT

When working in a non-computer environment Lorna saw herself as a source of authority and knowledge. Activities were largely teacher-led, and although the pupils could interact with the activities they did not have the same control over their learning that they experienced when working with the technology. She believed that her role as a teacher changed when pupils were using computers, because the technology was seen to provide the knowledge base while she acted as "... a facilitator circulating among groups...being literally amongst their learning," a role that she had only aspired to previously. She also provided technical support where necessary.

5.9.8.3 Evidence of pupils' attainment and motivation

Lorna had evidence that the use of ICT did have an impact on teaching and learning and increased motivation from her own research project the 'Enhancement of teaching and learning in modern foreign languages through the development of ICT', which she carried out at her previous school.

Targeted classes completed a qualitative questionnaire every four weeks over a period of six months. Learning was also measured over the period by comparing pupils' test results with previous results.

Results of the pupils' questionnaire indicated perceived learning outcomes for most (eight out of 11) classes from years 7 to 11 in listening, and for some classes in speaking (four out of 11), writing (two out of 11) and reading (one class). Lorna concluded from the evidence collected that there had been a positive effect on students' motivation, behaviour and learning gains as measured by internal test scores over the period.

5.9.8.4 *Future developments*

Lorna was aware that prior to her arrival at her present school the use of ICT was minimal in the department. She was aware that, working in a girls' grammar school with good examination results, teachers felt pressurised to maintain the status quo, and they believed that they did not have the time to integrate computers into their teaching. Enthusiasm for the use of the technology throughout the department was mixed, although she hoped that as colleagues experienced and saw the benefits of its use for themselves, attitudes would become more positive. Given these provisos, the school had drawn up a plan for the development of ICT in the short and medium term. She proposed that each teacher would prepare an ICT lesson plan for every module of work, which would then become a shared resource. Teachers could then access the ICT lesson-planning folder so that over time ICT would become integrated into the department's scheme of work.

5.9.9 Breeda

5.9.9.1 *Lessons using ICT*

It was not possible to observe any of Breeda's lessons, but through the interview she reported the ways in which ICT was being used in geography teaching in the school. For several years, year 8 pupils had been using computers, along with books and other resources, to research the Amazon. Working in groups, the pupils used the internet to find out information and put this into multimedia presentations, which were then presented to the class. The teachers would help individual pupils to decide what information was relevant to the topic about the Amazon, and how this related to other information they collected.

5.9.9.2 *Pedagogical practices of the teacher regarding ICT*

Breeda believed that her role was more interactive when pupils were using the technology, although this was often more technical than educational, for example discussing the visual aspects of screen displays when using presentation software. She believed that using the internet to find out information made the pupils more active learners, and as a result they remembered more about the topic. The locus of control moved away from her to the pupils, which gave them "... flexibility, individual choice of the way they want to approach it and the information they want to select." If, instead, they had been answering questions from a worksheet, they would all have produced very similar responses. The group presentations on the other hand were very individual, and the pupils learned from each other. She also believed that they were able to cover more material than they would have done otherwise, which was an important factor as Key Stage 3 pupils only had one geography lesson a week. She had analysed pupils' attitudes to the work as part of her NOF training and had found that they enjoyed, in particular, doing the actual research and listening to each other's presentations, and they felt that working in this way had helped them learn. The technology department encouraged the pupils to ask each other for technical help before asking a teacher. Consequently it was a more co-operative working environment.

5.9.9.3 *Evidence of pupils' attainment and motivation*

Breeda found that the technology enhanced learning in a number of ways, for example it was a great motivator when practising map work skills. Year 7 had recently used a Geographic Information Systems site, provided through the local education authority, which enabled them to print off aerial photographs and map overlays of the area in order to identify places of interest prior to a field visit.

She felt that the motivational factor did enhance the pupils' learning. She believed that the quality of the multimedia presentations, which are assessed by the teacher and by peer review, provided some evidence of pupils' learning. The feedback presentation was "more attractive" and pupils were "more pleased" with their work, but she was not sure whether their understanding of the geography had improved. Similarly, although the end of year examinations showed how well pupils were able to answer the questions, and showed how much they remembered, she had reservations about whether they were actually doing better than they would have done using other teaching methods. She also felt that some computer-based work was not "sufficiently testing". For instance in the map skills program, after several attempts pupils were given the answer, which she was not sure was helpful.

5.9.10 Jonathan

5.9.10.1 Lesson using ICT

No lesson was observed, but Jonathan described a year 12 lesson on physical landscapes. Previous lessons had focused on how river landscapes had evolved. This particular lesson made use of a CD-ROM that enabled students to search for suitable images, download them and annotate them with their ideas and interpretations using skills and understanding that had been modelled by the teacher in previous lessons. The students worked individually but exchanged ideas and discussed their work with each other. The students were set problem-solving tasks involving interpreting and explaining images about river formation from the CD-ROM. The teacher was able to circulate and discuss questions with pairs of students.

Similar activities are carried out with year 10 groups either using resources based on CD-ROMs or from websites. Jonathan also describes a year 10 project on Nairobi, where students selected pictures from an image bank and annotated them to create what Jonathan describes as a mind-map of their understanding.

5.9.10.2 Pedagogical practices of the teacher regarding ICT

Jonathan uses a computer suite with one computer per student for about an hour each month, and also sends students to a remote computer facility during his lessons for about one hour per month. A key feature of his teaching is that he sets computer-based homework where students access materials that he has prepared on the intranet for about an hour each week.

Jonathan sees ICT as providing resources for problem-solving tasks in geography, particularly those tasks where images are important. Previously a small number of images were provided on paper – photographs and textbooks. Use of CD-ROMs and the internet enables a much larger bank of images to be made available to students, and tasks can be set in which students select, interpret and analyse these images.

Typically Jonathan prepares tasks for year 10 and year 11 students and A-level students that involve problem-solving with reference to various resources including textbooks, videos, CD-ROMs and websites depending on which are more appropriate for the particular task. The students work individually on these tasks, but discuss their ideas with each other. The teacher circulates to support and interact with them. Some of the ICT-based tasks are carried out during lessons when Jonathan books a computer room. Others are set for homework, where students access activity sheets that include lists of URLs from the intranet.

Jonathan intends to provide students with access to all lesson plans and references to resources in electronic form. At present most students make paper-based notes but Jonathan is encouraging them to make their own electronic notes which may include annotated pictures and diagrams.

Jonathan's particular passion is developing thinking skills, and he sees it as important that students focus on organising their ideas. ICT supports this by providing resources and facilities to organise the notes that students make as they think.

5.9.10.3 Evidence of pupils' attainment and motivation

Jonathan achieves better results with his students than other teachers. For example, in year 11 the value-added effect is + 9 to + 1.4. Jonathan believes that his good results are due to his focus on developing thinking skills, and he sees ICT as supporting him and his students in this regard.

5.9.11 Robert

5.9.11.1 Lesson using ICT

Two of Robert's lessons were observed. The first lesson he described as a fairly typical year 12 lesson. The class consisted of a group of nine students, and the lesson was on DNA fingerprinting. At the start, students examined the results of an experiment that they had set up in the previous lesson, where they had worked in small groups to carry out gel electrophoresis. The teacher managed a class discussion and drew out the key principles of the experiment to remind students of the procedure. The experiment had not worked very well, but the purpose was for students to gain understanding of the techniques. The students then gathered around the interactive whiteboard to look at a simulation of an experiment that the teacher had downloaded from the internet. Robert asked a student to work through the procedure, which was done by dragging test-tubes and other equipment around on the screen while the teacher explained the process.

The teacher also provided the students with handouts that outlined the stages in the process for DNA fingerprinting. This was followed by a question-and-answer session in which the main ideas behind the process were drawn out. This was supported by a multimedia presentation.

The second lesson was with a group of 21 GCSE students on the theme of blood groups. This was an hour's theory lesson in which the students were seated in rows facing the front of the room and the interactive whiteboard (the room was a laboratory with fixed benches). The teacher introduced the lesson by explaining its focus and the learning objectives. There followed a brief question-and-answer session about blood groups in which students were asked about their own blood groups. The teacher used a foam model of a red blood cell with pieces of Plasticine representing antibodies to explain the characteristics of blood cells from people with various blood groups. Students were then asked to make notes in their books of the key ideas and the teacher walked around asking questions of small groups and answering students' questions. The model of the blood cell was passed around the class.

The teacher then showed a cartoon that revised key concepts of blood and briefly mentioned blood cell types. A question-and-answer session was conducted on blood transfusions by asking questions such as "If John was blood group A could his blood be used for transfusion to James who is blood group O? Why?" The students then made their own notes about blood transfusions. The teacher drew a table on the whiteboard showing donors and recipients and asked students to copy the table filling in the possible transfusions. The teacher circulated and checked the students' work. The grid was filled in on the interactive whiteboard by the teacher, and the results saved before setting homework. The students were on task and interested throughout the lesson.

5.9.11.2 Pedagogical practices of the teacher regarding ICT

Robert describes the most important use of ICT as enabling him to explain and discuss with students concepts that involve images of objects that cannot easily be seen, such as blood cells and, even more importantly, simulations and animations of dynamic processes. He believes that students find these processes hard to understand, and that understanding can be improved by providing a range of different ways of visualising and explaining them. He finds material on the internet and builds it into teaching sequences using software specifically designed for whole-class teaching with interactive whiteboards. He also makes use of cartoons because he feels that this adds interest to the lessons for the students.

The availability of the interactive whiteboard has enabled him to prepare a range of resources for different classes that he can use from year to year and continue to develop. He uses the interactive whiteboard for most of his lessons and finds it particularly useful for the theory-based lessons. Robert regularly invites one or two students to interact with the board while he gives some explanation.

Robert's theory lessons typically consist of a series of activities. Some activities are based on whole-class discussion, usually supported by interaction with the whiteboard, but also using other visual aids, for example the red blood cell, and other activities focus on students' individual work, particularly note-making or answering questions in writing. During the latter activities students were observed to be discussing their ideas with each other, although the activities were not specifically designed as group activities.

Another type of activity that Robert uses occasionally, mainly as a revision task, is to ask students to research a topic and produce their own multimedia presentations in small groups. He believes that this helps them to consolidate their knowledge by having to organise and present it for a different audience.

5.9.11.3 Evidence of pupils' attainment and motivation

Robert feels that the students enjoy watching the animations and cartoons, and hence are more attentive during lessons. He believes that they develop a better understanding of dynamic processes by being able to watch them as simulations and interact with them. Robert feels that students give better explanations of dynamic processes now than previously. A-level results have improved significantly over recent years, which corresponds to the increasing use of ICT; for example the percentage of A–C grades in biology in 2001 was 34.48 per cent (29 students) rising to 68.18 per cent in 2002 (22 students). There may of course be other factors influencing these results.

5.9.12 Aloysius

5.9.12.1 Lesson using ICT

No lesson by this teacher was observed, but instead the website that he has developed was reviewed. This website, for the geology A-level course, is intended to make available all the materials for students to enable them to do the course almost independently of the teacher. The website contains the syllabus, schemes of work, a knowledge audit based on multiple-choice tests, and a series of worksheets and activities.

Aloysius has prepared a multimedia presentation for every lesson, but he does not always use them because of the availability of rooms and hardware. In each lesson, however, he does point students towards the relevant resources on the website so that they can follow up the activities in their own time.

Aloysius outlined a GCSE lesson on weathering with a year 10 group. It started with a question-and-answer session where they made notes. Students then carried out a practical activity on identification of rocks to recap their knowledge. Aloysius then used a website on weathering to explain and illustrate some of the dynamic processes. He gave the students the URL so that they could follow up the ideas in their own time. Occasionally Aloysius sets students to work in groups to produce their own presentations by researching material from the internet. He usually gives different topics to different groups.

5.9.12.2 Pedagogical practices of the teacher regarding ICT

Aloysius uses ICT to provide a complete set of resources for his lessons that students can access at any time. He uses ICT in his lessons when he needs to provide a wide range of resources, such as images. For example:

“I can get up to 1,000 photographs of a trilobite in a quarter of an hour's work. They (the students) will be fed up with actually seeing trilobites as the end of it but they will actually, at that stage, know how to recognise a trilobite.”

He also uses ICT to provide simulations and animations of dynamic processes. He believes that students need opportunities to visualise and interact with these processes in simulations in order to develop their understanding.

Aloysius suggests that students are getting a richer, broader perspective on their knowledge by being given access to a wider range of resources, rather than by being limited to the small number of illustrations that can be presented in a textbook.

Aloysius also makes some use of simple multiple-choice assessments that he posts on the intranet. He sometimes uses these in whole-class discussions. He can then present a quick illustrated quiz to the class during a lesson which he feels is more interesting and entertaining than a similar paper-based activity. He does sometimes ask students to work in groups to develop their own presentations on topics where he feels it is worthwhile to spend more time on the research and where no other practical activities are feasible. He tends to use this approach more with sixth-form students than with younger students, because he feels there is a great deal to cover in the GCSEs and less time.

5.9.12.3 Evidence of pupils' attainment and motivation

Aloysius does not think that the use of ICT by his students had improved their attainment particularly. Another more experienced teacher in his department, who uses much less ICT, achieved similar results with his students. However Aloysius believes that his students receive a much richer learning experience and access a broader range of content. He also believes that they are developing study skills that will be useful to them in lifelong learning.

5.9.13 June

5.9.13.1 Lesson using ICT

This teacher was not observed giving a lesson, but a business studies module was described in which year 12 students worked independently from home using material on the school website. The students were given direct links to up-to-date economics websites and schemes of work, and deadlines for assignments were placed on the website so that students were aware of what was expected of them.

5.9.13.2 Pedagogical practices of the teacher regarding ICT

June sees ICT as providing a resource for students to use both during their lessons and to enable them to continue their studies outside school hours. By giving students good access to their course syllabuses, schemes of work and expectations, June expects that students will become more independent as learners.

The other main aspects of ICT that June sees as important is the ability of the interactive whiteboard to support teachers in providing resources for students that enable them to visualise processes. She believes that this helps students to remember, because they can visually focus on the ideas.

5.9.13.3 Evidence of pupils' attainment and motivation

June believes that it is essential to use multimedia in teaching and learning because students are using it in their own lives. The school is achieving good results and generally improving, which June believes is due to good teaching that integrates ICT. June suggests that it is very difficult to show the effects of ICT alone. As an ICT teacher, she has been making good use of ICT in her teaching for a long time, so it is not possible to provide evidence of recent improvements related to increased ICT use.

5.9.14 Gordon

5.9.14.1 Lesson using ICT

This teacher was not observed giving a lesson, but a number of lessons were described and explained. A chemistry lesson where students needed to understand the sequence of the crude oil production process was supported by the use of a series of animations from the BBC website using a data projector and whole-class discussion. Gordon described a question-and-answer process where he would present a small sequence of animations and ask the students questions such as "What's happened there?" and "What do you think this is?" Gordon was able to replay the animation

a number of times and ask different questions so that students could focus on the steps in the process. The next stage was for the students to draw and label diagrams to explain the process.

Other examples that Gordon described included chemical reactions, especially those that were too dangerous to conduct in the laboratory. Gordon also described examples where automatic data collection has enabled students to relate their understanding to the real world. For example, they have a station that monitors carbon monoxide levels so that they can actually check the level of carbon monoxide throughout the day and discuss the significance of changes in level. This activity is followed up by looking at a website that contains data about national air quality so that students are able to relate their discussions to real data.

Gordon has also used digital video with classes. For example, in lessons on food tests the first activity is to try and pull apart the process to separate it into a series of about six frames on the storyboard. The students then have to draw what they thought was going to be seen and create a caption with what it might be sensible to say. Each group has their own activity to do and they carry out their food tests. The students put the videos together as an extra-curricular activity and then, during a later lesson, they play the videos back and are able to discuss the processes.

5.9.14.2 Pedagogical practices of the teacher regarding ICT

Gordon suggests that there are two main ways in which his teaching has changed with the use of ICT. First he is able to show students things in ways that were not possible before – in particular simulations and animations of processes. Gordon feels that ICT is particularly useful for supporting discussions and question-and-answer sessions about dynamic processes. Secondly, he has been able to produce materials for students to use and to make them much more easily accessible by putting them on the internet. With sixth form groups he is encouraging students to bring a set of notes that they may have accessed from his website to the lesson, and then to talk about the meaning of the material and spend more time on practical exercises.

An additional type of activity that Gordon feels has value for learning is data logging with real-time graphing. This is particularly useful for examining concepts like speed and acceleration where you can focus on the concept rather than spending time on drawing graphs.

Another use for ICT that Gordon sees as important is for students to communicate their understanding. Some sixth form students have been able to produce animations of processes and bring them into school to show the rest of the class, and that then forms the basis of a class discussion.

5.9.14.3 Evidence of pupils' attainment and motivation

During the lessons on the crude oil production process, Gordon assessed the students' understanding by examining the diagrams they had drawn to illustrate the process. He found that the students that he would have expected to do very well did indeed do so, but in addition those who normally found difficulty in describing such processes and who were often less motivated did produce very good descriptions, which suggested that they had understood the process.

5.9.15 Sajeda

5.9.15.1 Lesson using ICT

Sajeda describes a lesson that she conducted at her previous school with a low-ability set, where they used a suite of computers attached to a science laboratory. The students had worked on a circus of experiments in which they logged data and interpreted the results from the graphs that were produced. This was motivating for these students and enabled them to focus on interpreting the data rather than drawing graphs. For their homework, the students were asked to produce a newspaper article based on the activity that they enjoyed the most. This practical lesson was a follow-up to the theory lesson to enable them to use the understanding that they had acquired.

5.9.15.2 Pedagogical practices of the teacher regarding ICT

Sajeda believes that for these low-ability students the practical work with computers is motivating and also enables them to practise some skills that are very difficult for them. For example some of

the students were visually impaired, and using digital thermometers is much easier for them than finding the meniscus on a standard thermometer.

Sajeda also sees value in using simulations of processes. For example with her GCSE classes studying the Haber process for the production of ammonia she has used a simulation on a data projector for a class question-and-answer session. Students are asked to think about how changes in temperature and pressure affect the process, so they predict the results and then check them. Sajeda explains how the use of this kind of simulation has the advantage that students can change the values of a number of variables and see the effect on the output graph very quickly, whereas any other mechanism would be much more time-consuming. Sajeda sees the role of the teacher in these activities being to prompt the students in their thinking. Students interacted with each other to make suggestions about how to proceed with the simulation.

5.9.15.3 Evidence of pupils' attainment and motivation

Sajeda felt that the GCSE students were able to give clearer explanations following the use of the simulation of the Haber process. This middle-ability set normally found difficulty in expressing their understanding, but their explanations seemed to be much clearer than usual, which suggests that understanding was improved by the activity.

5.9.16 Suzanne

5.9.16.1 Lesson using ICT

A year 7 lesson was observed in the art room where two PCs were provided side by side at the edge of the large room. The rest of the class was working on an ongoing project that focused on landscapes, thinking about line in landscapes, and about textures and composition. In this project the students had been out into the park next to the school and each had a small area to draw so that they composed their landscapes thinking about how things overlap, and what goes in front and behind. They also were asked to consider the different textures, colours, sizes and scales within that composition. Suzanne was aiming for them to understand composition through the landscape project.

The activity on the computer was designed to follow on from and develop this understanding of composition. Suzanne aimed to encourage the students to use the understanding of composition which they had developed through the landscapes project to think about developing their own still life composition on the computer.

The two students sat next to each other, but worked individually on their compositions. Suzanne explained the task to them at the start of the lesson and gave them a worksheet to remind them of the task and its purpose and of the main tools that they should use in the graphics program. They discussed their ideas with each other, to some extent, and Suzanne came to see how they were getting on from time to time and discussed their ideas with them. The students decided that they wanted to work from a real still life composition, so they selected a bottle and a couple of cartoons and made a composition. This had not been Suzanne's original intention, but she realised that they needed a starting point rather than making a composition from their heads. She helped them to select and arrange the still life.

Looking at the work that the students had done, after the lesson, Suzanne felt that they had made use of line and colours in a similar way to the way they had explored in the landscape project. For example one had used the spray can so that the colours were a little more muted for the background areas, whereas bold thick lines were used towards the front.

5.9.16.2 Pedagogical practices of the teacher regarding ICT

Suzanne's pedagogy for using ICT follows from and integrates with her view of pedagogy for learning and teaching art. Typically she outlines the purpose of an activity for the students and brings out the ideas in class discussions. Students generally work individually on their projects, but they are arranged in small groups and they discuss their ideas with each other while they are working. Suzanne encourages this discussion as she circulates and talks to individuals and small groups about their work and the ideas they are developing. She allows them a fair amount of

freedom with the way they work, for example she enabled the students working at the computers to change the approach from her original intention because they needed the concrete stimulus of the still life arrangement in order to focus their thinking. She also encourages students to think about the main ideas that she wants them to learn about, for example, in the current project these are line, form, background and foreground differences. Suzanne sets a task on the computers in her art room that complements the current task on which the class is working, and takes the pupils on a bit further with some of the ideas.

From time to time Suzanne books the computer suite for various classes and uses software such as animation or publishing software to develop particular aspects of art and design. She also sometimes sets students homework where they investigate a particular artist or type of art on the internet.

5.9.16.3 Evidence of pupils' attainment and motivation

In the lesson observed, Suzanne explained how the computer-based activity had extended and complemented the main project, and hence contributed to students' understanding. Suzanne sees the use of ICT as integral to learning art and design. She explains that there are many more digital artists becoming well-recognised and they are making more work that starts on the computers themselves rather than manipulating images that had previously been scanned into the computer.

5.9.17 Secondary school case studies – conclusions

The studies reported here revealed some similar practices to those found among the primary school teachers, although the way the ICT resources were distributed affected secondary teachers' practices differently from primary teachers. The conclusions presented in this section will be extended further at the end of the report. Specific issues have been revealed which are linked to the ICT resource being used, the teacher's knowledge of the subject and an understanding of the contribution ICT can make to the subject and to pupils' learning and attainment.

5.9.17.1 Selecting the ICT resource

The cases reported here support the findings from the literature which show that the majority of teachers use the ICT resources available rather than take the initiative of buying ones specific and relevant to their own subject. This results in the teaching possibilities being controlled by the ICT resources available. For example, many of the teachers reported using electronic whiteboards which were purchased for the school. Only a few teachers reported using subject-specific software which linked directly to the content and purpose of the curriculum. This ICT resource selection process affects the way in which teachers use ICT in the lessons.

5.9.17.2 Teachers' knowledge of the potential of ICT

In spite of teachers often being limited by the ICT resources available to them, all the teachers reported in the case studies were using selected ICT resources for interesting and challenging activities with their pupils. The knowledge teachers had about the scope of the ICT resource was influenced by their own expertise. For example, for those teachers who professed not to have significant experience in using spreadsheets, their use was mainly focused on using computers for pupils' multimedia presentations to promote class discussion. In such cases the focus of the ICT activity was on presenting knowledge rather than exploring new knowledge through concepts and processes. As was reported from the literature review, this meant that in some cases the learning of the pupils was focused around the multimedia skills rather than the subject knowledge.

However, there were other cases of a teacher changing the whole way they worked through the use of ICT. For example, although Charlotte claimed just to be a facilitator, she had radically changed the way music was taught, but in order to do this she needed a substantial understanding of the potential of the different ICT resources for use in music teaching. Additionally, she needed to know how to change her lessons and incorporate innovative ICT activities in the curriculum.

5.9.17.3 Confidence in using ICT

The evidence from the research has shown that teachers' abilities to use ICT in their lessons are influenced by the confidence they have. All the teachers in our case studies were confident users of the ICT applications and devices they chose to use. However we need to bear in mind that, first,

many of the teachers were focusing on a specific ICT application or device, and therefore might not be confident to use a wider range of ICT applications. Secondly, the teachers in these case studies are all innovative teachers, keen to use ICT, which was why they were selected for this project. This implies that other less enthusiastic teachers are likely to be constrained by different confidence levels and ICT uses much more than the teachers in this report.

Another aspect relating to confidence is the teachers' approach and role when using ICT in their lessons, which in some cases involves passing the leadership role over to the ICT environment. "I am mainly the facilitator" for example. This can imply that there is sometimes a lack of confidence in interacting with the class and the ICT environment during the lesson.

5.9.17.4 *Beyond the lesson*

A very important outcome from this research, which is supported by the case studies, is the conviction, mentioned above, of many teachers that they change their role from a leadership position to a facilitating role in the lessons. Evidence from the literature has led to researchers concluding that the pedagogy of the teacher is radically changed by the adoption of this new role when using ICT in teaching. However, these researchers, and also many teachers, fail to consider adequately that a major part of the teachers' pedagogy is in the planning, preparation and follow-up of lessons. None of the teachers in our case studies would have been able to make such imaginative uses of ICT in their lessons without knowing how to plan the lesson appropriately and without careful lesson preparation beforehand. This means that they still have a mainly leadership role in their overall teaching because they have planned the direction of the learning. Where some studies have shown that little planning has occurred, the evidence is that the pupils' work was unfocused and led to less than satisfactory outcomes.

5.9.17.5 *Listening to pupils*

As with the primary school case studies, the teachers reported that by having pupils collaborating in pairs at computers, or through whole-class discussions using an interactive whiteboard, they were able to listen to pupils' comments more frequently, individually and in more depth. For example, one teacher reported that the pupils who hardly ever spoke were motivated to discuss the work with their colleagues, and the teacher was able to learn much more about what such pupils really understood.

The teachers also stressed the importance of getting feedback from pupils through written work. For example Hazel collected printouts of pupils' work at every stage of the designing of their control programs. This, she claimed, helped to make their thinking more visible.

The Use of some ICT packages also enabled pupils to improve their ability to explain specific processes more logically. Robert claimed that by getting pupils to produce a multimedia presentation of a biology experiment, they were then encouraged to provide better scientific explanations of dynamic processes than previously when they wrote up experiments by hand.

These, and all the other examples in the case studies, provide additional evidence of the importance of teachers knowing about the scope of ICT and how it will affect pupils' attainment. These conclusions are discussed further in the final conclusions section (Section 7).

6 Focus group procedures and results

As explained in the method section earlier (section 3.6.6), the teachers in the case studies were invited to attend a focus group meeting at King's College London to discuss issues which emerged from the case studies. The purpose of this meeting was to see if we had clearly understood the teachers' pedagogical reasoning and their uses of ICT in their teaching. Although we invited all 26 teachers to the focus group, only seven were able to attend, due to many other commitments and some schools having started their holidays.

In order to focus the discussion around the issues which were emerging we produced a set of statements about the uses of ICT (see Appendix 9). Teachers were then asked to consider and comment on which ones they felt would be valuable to pupils' attainment and why. Examples of some of these are:

- In small groups pupils role-play a story or episode from fact or fiction which they video. They then edit the video to produce a film or multimedia presentation for a particular audience.
- The whole class brainstorms about a topic to produce a mind map on the interactive whiteboard.
- Pupils work at a cluster of computers in the classroom on an art, design, data-logging or problem-solving task that focuses on some specific learning objectives for the current topic, while the rest of the class work on other activities.

6.1 Meeting procedure

The meeting began with an introduction about the work of Becta, outlining the ICT and Attainment project. The reasons for the meeting were outlined: that one visit is not sufficient to gain an accurate picture, and because of the need to go through ideas again in case a rethink was needed.

The teachers were asked questions about their main reasons for using ICT in their teaching, and to comment on the 11 statements of ICT use (see Appendix 9), stating which ones they felt were most important and whether they felt anything was missing from the list.

They were asked about pupils' interactions and the levels of ICT knowledge and skills required of pupils and teachers.

Participants were also asked about what barriers there were to successful implementation of ICT use.

6.2 Focus group conclusions

Below is a summary of the conclusions from the focus group meeting.

The teachers focused on the uses of ICT which were most important to them. Although they did discuss the other ICT uses (see Appendix 9), the uses which the teachers spent most time discussing were number 10 (pupils construct models to investigate the relationship between variables in a process) and number 6 (pupils work collaboratively in groups during lessons to research a topic from the internet, obtain material and develop a multimedia presentation, poster or newspaper).

6.2.1 Helping the teacher

The teachers considered the role of ICT in making important contributions to schools to help teaching and to help deliver the curriculum:

- 1 ICT can help teachers make the lesson more interesting.
- 2 ICT helps teachers explain things more clearly to learners.
- 3 ICT can be used in most curriculum subjects.
- 4 ICT encourages teachers to vary the ways in which they organise the pupils in their lessons, eg computer partners, pairs, larger groups.
- 5 Teachers can prepare for relevant activities beforehand, eg selecting suitable websites or preparing a folder of images.
- 6 An important activity for the teacher is to prepare tasks requiring pupils to demonstrate their knowledge.

6.2.2 Role of the pupils

A range of the roles of the pupils in using ICT were identified by the teachers, although these are not confined to ICT activities:

- Individual workers
- In pairs, ie sharing, taking turns

- Research teams

6.2.3 Advantages for learning

Many advantages were reported by the teachers, an important one being that pupils could control the learning process and see the results of their actions and decisions.

- Pupils can change variables in mathematics and investigate mathematical relationships interactively.
- Simulations help pupils to control/distinguish variables.
- Pupils can change one variable at a time in a simulation.
- Pupils can collect data and do the 'experiment' on the interactive whiteboard.
- Using simulations challenges conceptual understanding.
- Pupils can hypothesise and predict outcomes of processes.
- Using ICT enables pupils to learn how to explain things to others.
- The teacher can focus on the more important task of helping pupils in scientific thinking.
- Using electronic whiteboards helps the teacher introduce the theory behind topics.
- ICT encourages pupils to reflect on their own work.
- ICT enables pupils to evaluate theirs and other pupils' work.
- Having to explain the activity to others first requires clarification in their own minds.
- Pupils can access more knowledge during school time.

6.2.4 Level of ICT skills of teachers and pupils

Confidence was important to the teachers, but with simulations they believed that a wide range of ICT skills may not be needed. However, teachers may need more specialist expertise for modelling, for example in spreadsheet programs, or using other modelling software.

The teachers said that some pupils are very confident in using ICT and they do not panic when things go wrong. They do not have the same fear because ICT is more familiar to them. However there are an unfortunate few pupils who have little or no computer experience outside school.

Fear was regarded as a problem for teachers generally. There was disagreement about the pivotal role of the teacher in the lesson, but general agreement that questioning the pupils to challenge their thinking needs to be conducted by teachers during the lesson. The teachers listed a range of skills which they needed when planning to use and actually using ICT:

- Preparing and planning ICT-based lessons, which requires thinking in a logical sequence.
- Teaching pupils to do multimedia presentations.
- Assessing presentations for both content and processes.
- Reinforcing key concepts.
- Making the learning activity relevant to the curriculum and the pupils themselves.
- Bringing on understanding through posing challenging questions.

Teachers and pupils need an awareness of audience, eg parents, teachers and other pupils.

6.2.5 Levels of support for internet searches

It was agreed that teachers needed a structure to focus research tasks when using the internet, and they needed to consider the following:

- Teachers need to consider the purpose and learning objectives for using the internet.
- Many sites had too advanced language for young learners.
- Sites which had more graphics helped interpretation for pupils.
- There is only a finite amount of time for pupils to complete the task in a lesson or lessons.
- Even at A-level, students can meander unproductively when conducting research.

Some of the constraints above can be overcome by providing pupils with a list of websites so that their searches are more focused.

6.2.6 Barriers

The teachers suggested the following barriers which might prevent many teachers from using ICT:

- The occasional reluctance of the headteacher to invest in hardware.
- Teachers' inadequacy and lack of training and confidence.
- Insufficient access to hardware.
- Staff fear, although internal training within the school can overcome this.
- An apparent dearth of educational software, other than standard office packages.

6.2.7 Pupils' attainment

The teachers agreed that there was evidence of the difficulties in disentangling ICT from other activities when trying to determine what effect ICT has had on pupils' attainment. Different types of evidence, other than tests, supported the claims that ICT helped pupils' attainment. These included evidence that:

- Primary pupils were able to write more coherently about school visits.
- Pupils are more engaged with the learning.
- Pupils are more critical and reflective, showing more understanding.
- The activities were perceived by the pupils to be more relevant, therefore the knowledge being taught is more likely to be retained.

Finally, it was felt that teachers' and governments' expectations are higher now than 20 years ago, because of access to a greater range of information through the use of ICT.

7 Conclusions

The conclusions presented here are drawn from the review of the empirical evidence and theories about pedagogy published in the literature and illuminated by relevant evidence from the case studies of innovative teachers using ICT. For specific conclusions about the primary and secondary teachers' case studies please see Sections 5.8.11 (primary) and 5.9.17 (secondary), parts of which are also presented here. The evidence for this review is drawn from over 350 publications in the academic literature, which include mostly research papers, reports, web-based publications and other types of documents, as explained at the beginning of the report. It should be noted that there are many other publications which could be reviewed, but which were beyond the scope of this four-month literature review. However, the majority of those reviewed for this project were reliable reports of a large range of studies conducted to evaluate the effects of teachers' pedagogical practices on pupils' attainment using ICT. The research methods used to measure the effects reported in these studies are discussed below in Section 7.9.

The evidence from this literature review shows a strong relationship between the ways in which ICT has been used and the resulting attainment outcomes. This suggests that the crucial component in the use of ICT within education is the teacher and their pedagogical approaches. Excellent software, reliable hardware and resilient networks, important though they may be, will have no effect on attainment if teachers are not enabled and educated to use these resources appropriately.

7.1 Teachers' subject knowledge

The evidence presented from the review shows that the types of use of ICT and the ways it is used in lessons are influenced by the teachers' knowledge about their own subject. An example of this is the use of ICT in science in which teachers selected and used simulations to enhance their teaching of science (see Sections 5.3.5 and 5.4.3). These findings, and some of the case study findings, show that the teachers who integrated ICT into their teaching focused on the content and knowledge of their subject rather than using it as a new way of presenting pupils' work. They were able to extend the learning experiences of the pupils by, for example, investigating scientific processes or producing an historical multimedia presentation. There was a clear division between the teachers who chose ICT resources to fit within a particular topic and those who chose it to present the pupils' work in an innovative way, without any direct application to the topic.

The evidence shows that when teachers use their knowledge of both the subject and the way pupils understand the subject, their use of ICT had a more direct effect on pupils' attainment. This occurred more reliably when pupils were challenged to think and question their own understanding, albeit through them using topic-focused ICT software on their own or in pairs or through a whole-class presentation. The effects of using ICT to present and discuss pupils' work are less well researched, and therefore the effects on pupils' attainment are not so clear.

7.2 Access to ICT resources

An important influence on the eventual use of ICT in subjects and classes was the amount of ICT resources available to the teachers. In primary schools it was still frequently reported that teachers had only one or two computers in a class, which affected the way they used ICT. There are two conflicting trends here. First, for those teachers who had access to one or two computers in a class, pupils used the computer either working in pairs when the remainder of the class was working on other tasks, or they used them in rotation, so that everyone had a fair go. This was shown to have a restricting effect in some cases, because each individual pupil was only able to use the computer for a few minutes.

We reviewed many reliable studies which reported the contribution of using word processing on pupils' literacy skills. However, in practice, the opportunities for improved attainment were frequently limited because pupils had to hand-write their texts first, then get them corrected by the teacher, and eventually type them into the computer, possibly working in pairs. The effect of this was that there was no opportunity for them to use ICT to draft and redraft and reflect on their writing, even though there is a lot of research evidence which shows that this process significantly enhances pupils' literacy skills. Research in this area was reported by the first ImpacT project in 1993 (Watson, 1993), but was also reported 10 years later by the ImpaCT2 project in 2002 (Comber *et al.*, 2002; Harrison *et al.*, 2002; Somekh *et al.*, 2002). This shows that still more ICT resources need to be provided to schools, and teachers need much more training if they are to move forward in the way they use ICT for literacy and other skills.

On the other hand, some primary schools organised their resources differently, as is shown in the primary school case studies. One school, which had a pupil : computer ratio of 3 : 1, grouped the computers in clusters outside the class as well as having them inside. They also used a digital video camera to film drama presentations, which enabled the pupils to benefit from the use of ICT in a range of educational settings and through a range of experiences. The use of the interactive whiteboard by the case study primary and secondary school teachers showed first a change in emphasis from individualised computer-based work to whole-class teaching. However, it also showed a move away from using ICT resources with subject content to the use of a presentation tool to promote whole-class discussions.

The case studies reported here support the findings from the literature which show that the majority of teachers use the ICT resources available rather than take the initiative of buying ones specific and relevant to their own subject. This results in the teaching possibilities often being controlled by the ICT resources themselves rather than by the teacher and the subject. For example, many of the teachers reported using electronic whiteboards which were purchased for the whole school. Only a few teachers reported using subject-specific software which linked directly to the content and purpose of the curriculum. This ICT resource selection process affects the ways in which teachers use ICT in the lessons.

What is interesting here is that the majority of teachers in our case studies and in the earlier research seemed quite willing to accept the ICT uses imposed upon them by senior management. Many, apart from the headteachers and deputy heads, did not report any initiative to purchase specific ICT software which might be useful in their subject. In the study conducted by Preston *et al.* (2000), the ICT co-ordinators reported a great reluctance of other subject teachers to spend time reviewing ICT resources which might be useful in the teacher's subject. However, these findings do not apply to some of the enthusiastic teachers in our case studies and in earlier projects who pioneer the uses of ICT in their subjects.

One of the main features of many earlier research studies is that in order to investigate the effects of innovative ICT resources in schools, the researchers often introduced the resource into the school, which influenced the teachers' attitude and uptake of it in the classroom (eg Mellar *et al.*, 1994). Many of the more naturalistic studies can only focus on a limited range of ICT resources which the schools have opted to use.

7.3 Teachers' pedagogical knowledge

The teacher's own pedagogical beliefs and values play an important part in shaping technology-mediated learning opportunities. Whether this results in technology being used as a servant to reinforce existing teaching approaches or as a partner or extension of self to change the way teachers and students interact with each other and with the tasks is not yet clear from the research literature.

The extensive study by Brown *et al.* (2001) identified a range of characteristics which would enable teachers to teach effectively (see Section 5.1), which also apply to using ICT. These include developing significant learning strategies, exposing and relating the activities to children's existing knowledge and having consistency between tasks and objectives. It involves considering the inter-relationships with other content both within the subject and with that in other subject areas. The empirical evidence shows that if teachers clearly understood the scope and value of specific ICT resources and how these could be used to enhance the understanding of the subject, then the tasks would be more closely focused, with guided learning experiences for the pupils. Three main approaches have emerged from the data regarding the use of ICT by teachers:

- **Integrated approach:** planning the use of ICT within the subject to enhance particular concepts and skills and improve pupils' attainment. This involves a careful and considered review of the curriculum area, selecting the appropriate ICT resource which will contribute to the aims and objectives of the curriculum and scheme of work and then integrating that use in relevant lessons.
- **Enhancement approach:** planning the use of an ICT resource which will enhance the existing topic through some aspect of the lessons and tasks, for example, using the interactive whiteboard for presenting theory about a topic. In this approach the teacher plans to complement the lesson with an innovative presentation method to promote discussion in the class and overcome and visualisation problems.
- **Complementary approach:** using an ICT resource to empower the pupils' learning by enabling them to, for example, improve their class work by taking notes on the computer, or sending homework to the teacher by email from home, or using word processing for their homework.

In the literature and in the case studies all three approaches were used by some teachers and shown to enhance attainment, but the types of effect are different. In the integrated approach, the learning by the pupils was enhanced by confronting them with challenges to their existing knowledge and giving them deeper insights into the subject being studied. The enhancement approach could result in improving pupils' learning through presenting knowledge in new ways and promoting debates among and explanations by pupils. The complementary approach relates to the emancipatory paradigm of Kemmis *et al.* (1997) which suggests that pupils' learning can be enhanced by reducing the mundane and repetitive aspects of learning, such as handwriting essays and homework, freeing the learner to focus on more challenging and subject-focused tasks.

These different types of uses require the teacher to have an extensive knowledge of ICT and to be able to fit its use either into their existing pedagogy or to extend their pedagogical knowledge so they can accommodate ICT effectively in their teaching. Smith (1998) investigated the relationship between computers and views of mathematics from both individual and social constructivist perspectives. He argued that social constructivists, who believe that the learning context has a large impact on the learner, are more likely to take the position that computers alter the way we do mathematics. Individual constructivists, however – people who believe that the main outcomes are dependent on the individual learner and not on the influences of the environment – would be more likely to say that computers change the mathematics that we do. This means that some teachers

would enhance their mathematics teaching (the enhancement approach) by using an electronic whiteboard to demonstrate problems on the screen and stimulate class discussion, while other teachers may choose ICT modelling to extend the mathematical models which pupils can construct and investigate (the integrated approach).

This study identified the need to take account of students' prior conceptions, linking multiple representations, extending the range of manipulable objects and using software to reveal students' thinking. All of these require a deep understanding by the teacher about how their pedagogical knowledge needs to expand to take account of new ways of learning through the use of multimedia.

7.4 Teachers' knowledge of the potential of ICT

In spite of teachers often being limited by the ICT resources available to them, there are many examples in the literature of teachers having a good understanding of a particular resource. Many of the published studies reporting on the uses of ICT make it clear that most teachers do not use many different ICT resources, as advocated by the new Teacher Training Agency guidelines. All the teachers reported in the case studies were using selected ICT resources for interesting and challenging activities with their pupils. The literature review shows that the choice of ICT resources was not only influenced by what was available, but also by the subject and the teacher's expertise. Studies of science teachers reported the main use as being simulations and modelling, whereas English teachers used word processing and presentation software. Those teachers in our case studies who professed not to have significant experience in using spreadsheets mainly focused on using presentation software and/or word processing for pupils' presentations to promote class discussion. In such cases the focus of the ICT activity was on presenting knowledge rather than exploring new knowledge through concepts and processes using a simulation. As was reported from the literature review, this meant that in some cases the pupils' learning was focused around the multimedia skills, rather than the subject knowledge. There is a marked difference between primary and secondary school teachers' use of ICT, which is related to their knowledge of its educational potential.

Evidence from our primary school case study teachers shows that they mainly focus on specific ICT applications and resources to use regularly in their teaching, but not on many different applications. For example, one teacher used presentation software with an electronic whiteboard with most of her pupils, but never used spreadsheet or other modelling software. Another teacher used word processing, presentation software and interactive video for literacy teaching each week, but only used spreadsheets once a month. This pattern is repeated among all the teachers reported here, in both primary and secondary schools, and among many teachers in the previous studies we have reviewed.

7.5 Confidence in using ICT

Previous studies into teachers' attitudes to ICT (see also Cox and Abbott, 2004) have shown that the uptake and use of ICT will depend upon teachers' attitudes and confidence. The literature review here has focused mostly on pedagogical approaches, but there was much evidence to show a lack of confidence among teachers in using a range of ICT in lessons. The earlier evidence from Preston et al. (2000) showed that even some ICT co-ordinators and teachers rarely used any ICT application other than word processing more than once a month. All the teachers in our case studies were confident users of the ICT applications and devices they chose to use. However, in the focus group meeting several of the teachers said they were only confident in using the specific ICT resource which they had chosen, and were not keen to extend their ICT use to other resources. The teachers in these case studies are all innovative teachers, who are keen to use ICT (which was why they were selected for this project). This implies that other less enthusiastic teachers are likely to be constrained by different confidence levels and ICT uses much more than the teachers in this report.

Another aspect relating to confidence is the teachers' approach and role when using ICT in their lessons, which in some cases suggests passing the leadership role over to the ICT environment. Comments like "I am mainly the facilitator" for example. This can imply that there is sometimes a lack of confidence in interacting with the class and the ICT environment during the lesson.

7.6 Pedagogical practices of the teacher regarding ICT

The pedagogical practices of the teachers, reported in the literature and supported by the case study evidence, ranged from only small enhancements of practices using more traditional methods to fundamental changes in the philosophy of the teachers. These changes were in the way they taught their subject and the tasks required of the pupils. On the one hand, a few teachers were mostly replacing the blackboard and chalk with an interactive whiteboard, where the main additional advantages were that you could display educational software, or web pages, or store your board notes and diagrams and revisit them later in the same lesson or in a subsequent lesson. They also engaged the pupils more actively in class discussions, stimulated by the material displayed on the whiteboard and the possibility of entering new text, pictures and so on. On the other hand there were projects involving teachers who enabled pupils to act out and film drama presentations and interviews and then build storyboards around these, ending with pupils' presentations. This involved a change in the way pupils learned English and literacy by making much more use of audio and video materials, rather than focusing mainly on the written word. It was found that teachers' thinking and beliefs about teaching and learning were linked to what they did in the classroom and the choices they made in selecting how to integrate ICT into their teaching. A key feature of the more effective teachers was their use of effective explanations.

These results show that the most effective uses of ICT are those in which the teacher and the software can challenge pupils' understanding and thinking, either through whole-class discussions using the whiteboard or through individual or paired work on a computer. If the teacher has the skills to organise and stimulate the ICT-based activity, then either approach can be equally effective, as is elaborated in the following sections.

7.6.1 Organisation

It is widely acknowledged that teaching strategies are a crucial factor, and that these can be greatly influenced by the organisation of ICT facilities. The influence of the teacher in the lesson was recognised as a crucial element in the process. In instances where teachers provided limited supervision and guidance, there were often periods of unproductive activity. Evidence from the literature concluded that if ICT is to have a positive effect on pupils' attainment, then the technology should be used in a tightly linked fashion and support the underlying instructional approaches. It should be used as a tool for pupils' use in creating their own personally meaningful representations. The presence of the computer alone as a delivery system of static expert representations does not guarantee, and indeed may inhibit, the development of pupils' representations.

Laurillard (1998) reports observations that reveal how learners working on interactive media with no clear narrative structure tend to be unfocused. Teachers need to prepare instructional worksheets or offer supervision, thus imposing some form of organising structure in order to be productive. Thus one of the key benefits of interactive media – the greater learner control it offers – becomes pedagogically disadvantageous if it results in mere absence of structure.

The conclusion from the literature review is that failure to use ICT effectively is more likely to occur where teachers fail to appreciate that interactivity requires a new approach to pedagogy. Training and personal development involving coaching and mutually reflective activity is of the greatest help to staff. In other words, teachers need to consider what combination of teaching strategies and delivery media will best produce the desired learning outcome for the pupils. Teachers need to plan how the lesson will proceed and how the ICT resources will be used, which might involve a change in classroom practices.

The research evidence from the review has shown that teachers needed to employ proactive and responsive strategies in order to support, guide and facilitate learning. They also needed to monitor progress and maintain focus on subject learning, to encourage pupil reflection and analysis, to structure activities carefully and provide more focused tasks, to pace lessons realistically, and to support learning and revision by making available printed and other written resources. Evidence from the literature showed that even when pupils were using Logo and other open-ended software, the effects on attainment were more extensive when the teacher had planned the learning goals and tasks than when they left the pupils to acquire knowledge for themselves. This was supported by the teachers in the case studies who said, for example, that when pupils were searching for

information on the internet, even the A-level students needed some guidance and some structure to their work.

7.6.2 Collaborative work

An important outcome of pupils' use of ICT in pairs, groups or as a whole class through the use of an interactive whiteboard was that it enabled the teachers to gather more extensive feedback from the pupils by listening to their explanations. Although this is already done without the use of ICT through, for example, group work in primary schools and laboratory work in secondary schools, there were many reports of evidence of improved understanding by pupils having to make their explanations explicit and by sharing them with others. This was confirmed by the case studies. For example, one teacher reported that the pupils who hardly ever spoke were motivated to discuss the work with their colleagues and he was able to learn much more about what such pupils really understood.

There is also evidence from a number of studies to show that if pupils are put in pairs or groups, but their learning tasks are not planned on that basis, then no additional benefit for pupils' attainment will be achieved. There were several examples in the literature of one pupil in the pair or group being engaged in the learning task while the others became mainly observers. There were other examples where the main discussion among the pupils was either about some other topic of interest or often about the technical details for using the software. However, in the case of the latter, many teachers found this useful as a way of improving pupils' ICT skills, as was noted in the focus group meeting.

7.6.3 Insights into pupils' learning

The case study teachers also stressed the importance of getting feedback from pupils through written work. For example, Hazel collected printouts of pupils' work at every stage of the designing of their control programs. This she claimed helped to make their thinking visible and for her to identify errors of understanding among the pupils as they progressed through the learning activity.

Using some ICT packages also enabled pupils to improve their abilities to explain specific processes more logically. Robert, one of the case study teachers, claimed that by getting pupils to produce a multimedia presentation of a biology experiment, they were then encouraged to provide better scientific explanations of dynamic processes than previously when they wrote up experiments by hand.

There are many other examples of pupils revealing their understanding through building computer-based models (eg Mellar *et al.*, 1994), creating multimedia presentations, composing music and constructing websites. Teachers who have worked with pupils using ICT for these purposes have shown that they gain deeper insights into pupils' understanding and progress in learning than they are able to get through other forms of pupils' expression.

7.6.4 Pedagogy beyond the classroom

A very important outcome from this research, which is supported by the case studies, is the conviction of many teachers that they change their role from a leadership position to a facilitating role in the lessons. Evidence from the literature has led to researchers concluding that the pedagogy of the teacher is radically changed by the adoption of this new role when using ICT in teaching. However, these researchers, and also many teachers, fail to consider adequately that a major part of their pedagogy is in the planning, preparation and follow-up of lessons. None of the teachers in our case studies would have been able to make such imaginative use of ICT in their lessons without knowing how to plan the lesson appropriately and without careful lesson preparation beforehand. This means that they still have a mainly leadership role in their overall teaching because they have planned the pupils' work and direction of the learning.

In some studies where it was shown that little planning has occurred, the pupils' class work was unfocused and this led to less than satisfactory outcomes. There is therefore a fundamental misunderstanding by many teachers and even teacher trainers about how to incorporate ICT in their whole teaching programme. Teachers who have insufficient knowledge of the contribution which ICT can make to pupils' learning often assume that the main tasks are to familiarise themselves

with the software, prepare a pupils' worksheet to show how to operate the program and then use it in their lesson, having seen their more expert colleagues during an actual lesson. What they often do not see is all the pedagogical thinking, planning and preparation which goes into a good ICT-based lesson, as was carried out by the teachers in the case studies.

7.7 The effects of pedagogical practices on pupils' attainment

In the discussion above, and in the related report on ICT and attainment (Cox and Abbott, 2004), there is extensive evidence of ICT contributing to pupils' attainment. Benefits for pupils include, among others: enabling them to challenge their preconceptions; giving them the means of providing more powerful explanations; helping them develop better reasoning strategies; and developing their confidence in their ability to communicate their knowledge to others; helping them achieve more autonomy in their learning; and helping them relate their learning in a wider context. However, all the evidence presented in this report shows that these benefits are dependent upon the way in which the teacher selects and organises the ICT resources and how they integrate this use into other activities in the class and beyond.

There is still insufficient evidence from the literature of how a range of ICT uses might affect pupils' attainment. The greatest and most reliable evidence is from the focused studies and the case studies in which it is possible to link the specific learning outcomes to specific tasks promoted by the use of the particular ICT resource. The effectiveness of ICT use depends very much on the choices teachers make about which ICT resources to use and whether the teacher is able to link the use of such resources to particular learning objectives. In several of the case studies the main benefits reported by the teacher were through an approach which was not directly related to specific subject knowledge, skills and processes. But in other case studies the specific uses were more integrated into the curriculum, such as the primary literacy project and the secondary control project. An example of the range of approaches to using ICT was given during the focus group meeting when teachers listed their reasons for using ICT (see Section 6.2): ICT can help make the lessons more interesting; ICT can help the teacher explain things more clearly; and so on. One teacher who had integrated ICT into his science curriculum was able to produce a long list of benefits to pupils' learning of particular concepts in science.

What is clear from this study is that apart from a few exceptions, at present the uses of ICT are nearly always focused on specific aspects of the curriculum through the types of resources available. There are two clear areas where teachers have been shown to embed ICT in their teaching, and where this has enhanced learning:

1. Science and mathematics, through the use of simulations, modelling and other specific ICT resources.
2. English and literacy, through the use of word processing, multimedia presentations and interactive video.

In other subjects there is evidence of pupils' enhanced learning through either the use of an interactive whiteboard for presentation purposes, or the use of very specialised resources, such as music software for musical composition. All these uses and many others which could benefit pupils are dependent upon the decisions made by the teacher, and, as we have shown, this depends upon their pedagogical reasoning and understanding of the scope of the technology.

7.8 Pedagogical framework

Earlier we presented an emerging pedagogical framework (see Figure 5.5) to show how the teachers' and pupils' knowledge and beliefs will affect the learning outcomes when using ICT. The research evidence presented here shows how important these influences are on the 'affordances' which will enable pupils to benefit from the use of ICT. One of the implications from this model for teachers' uses of ICT is that teachers need to have sufficient knowledge about the topic or subject, and how this will be affected by the use of ICT, in order that they can make appropriate decisions about using ICT with their pupils. Those teachers who have achieved this have managed to do so by selecting ICT resources where they can be confident that they understand the benefits for their pupils. There is, however, a large gap between the teachers reported in this study and the majority of teachers not yet using ICT at all or only using it very rarely. There is also a large gap in knowledge and/or confidence among even many of the innovative teachers with regards to the

potential that a whole range of other ICT uses might have for their pupils' learning. This implies that teachers need to reflect on their current knowledge and pedagogy regarding ICT and embrace the following knowledge and expertise:

- Understanding the relationship between their subject and many different ICT resources.
- Being able to identify ICT resources which will contribute to the curriculum and subjects they teach rather than confine the use of ICT to the resources which happen to be in the school.
- Knowing how to use ICT resources which will enhance the learning of the pupils in the particular subject, eg the relative values of topic-specific and generic ICT resources, and online resources.
- Knowing how to prepare and plan lessons where ICT is used which will challenge pupils' understanding and promote reflection and thinking.
- Knowing which kinds of class organisation will be most effective for the learning tasks, eg individual/pair/group work or a whole-class presentation.
- Knowing how to challenge pupils engaged in ICT-based learning tasks.
- Knowing how to integrate ICT into their pedagogical practices which will complement the other teaching and learning activities and improve pupils' attainment.

These professional development requirements apply equally to primary and secondary teachers, because although primary teaching is often cross-curricular in its mode of delivery, all the topics within the primary curriculum relate to specific subjects and the associated concepts and skills.

It is clear from this research that in order that the majority of teachers could extend their range of ICT uses substantially, they need an enormous amount of time to develop their pedagogical as well as ICT skills. This may not be achievable in the foreseeable future because of the resources and teachers' time which this would require. An alternative approach to future developments of ICT in education may be to encourage teachers in specific subjects to focus only on those ICT resources which are most relevant to them and their subject.

7.9 Research methods of previous studies of ICT and teachers' pedagogies

There is still a debate about whether or not it is possible to measure the effects of teachers' pedagogy and uses of ICT on pupils' attainment, and there are clear reasons for some skepticism. First, as has been shown by previous researchers (eg Laurillard, 1993) it makes no more sense to try to measure the effects of ICT on pupils' attainment than it does to measure the effects of the blackboard or books on pupils' attainment. However, it does make sense to measure the effect on attainment of specific uses of ICT – for example the use of a simulation or an interactive whiteboard – and to measure the related effect of teachers' pedagogical practices and the learning context. In comparative studies (ICT-based and non-ICT-based lessons) it is often difficult to disentangle the effects of teachers' pedagogical practices from any effects of a specific ICT use which the researchers are trying to measure. This is because often the specific pedagogical practices and the ICT features are not measured in enough detail. Results from this study have shown that **specific uses of ICT** (using ICT for a specific topic and specific learning objectives) can contribute to pupils' attainment, and that these uses are influenced by the pedagogical practices of the teachers.

Examples of the specific uses most frequently reported in the literature and earlier in this report include:

- Simulations and modelling in science and other subjects
- Modelling environments and other software in mathematics
- Word processing for language and literacy
- The internet to extend pupils' subject knowledge
- Presentation software to develop pupils' presentation and literacy skills
- The interactive whiteboard to promote class discussions and pupils' explanations and presentation skills.

The methods used by previous researchers to measure the relationship between teachers' pedagogical practices and pupils' attainment when using an ICT resource include several types of approaches and research instruments, briefly commented on here and illuminated by the results of our case studies.

7.9.1 The researchers' knowledge of ICT-related pedagogies

The first requirement for researchers engaged in measuring the effects of teachers' pedagogies on ICT use is they must have the relevant subject knowledge of the topics being taught, because it is difficult to identify the relevance of the activity to the subject without this knowledge. Secondly, the researcher needs extensive knowledge of the ICT resources being used, in order to develop measures linked to specific learning experiences which might be promoted by the use of the resource.

7.9.2 Observing the lessons

Many researchers have measured teachers' pedagogical practices by observing and recording lessons in which ICT is used. For case studies where the focus is on measuring the relationship between teachers' practices and pupils' learning using an ICT resource, by observing lessons the researcher can identify the actions of the teacher and the teaching strategies which they adopt in their lessons. However, some studies have used this approach, but without always finding out the pedagogical reasoning behind the teachers' practices, nor the extent of preparation and planning prior to the lesson. As we have shown above, the researcher needs this information to be able to relate the teachers' actions to the reasons for using the ICT resource, to be able to identify the influence on pupils' learning. Therefore researchers need to use additional ways of collecting this information.

The earlier research done by the first Impact project (Watson, 1993) showed that teachers' pedagogical practices vary not only with the ICT resource they are using, but also with the class of pupils they are teaching. They also vary over time as a result of learning more about the ICT resource and more about the pupils' skills and what can be achieved in the subject. Pedagogical practices vary from term to term because some topics in the syllabus are more suitable for using ICT than others. Researchers who have observed a range of classes given by the same teacher over a long period have been more successful in obtaining a comprehensive picture of a particular teacher's pedagogical practices than those who only observe one or two lessons. Apart from the first Impact project there are very few reports where a range of classes have been observed with the same teacher. It was only possible to observe our case study teachers working in one lesson because of the four-month duration of the total project, therefore we only have data on how teachers used ICT in that particular lesson.

A third aspect, which is often left out of comparative research studies, is collecting data from classes who are **not** using ICT with the same or different teachers. This was a limitation in the Impact projects. If researchers hope to gather data in comparative studies which will enable them to say whether or not ICT has affected teachers' pedagogies, then they need to know what those practices are when the teacher is not using ICT, as well as when they are. This also applies to focused case studies for the teachers being studied. A good example here is the work of the science teachers reported in the review who were using simulations. It was observed that while the pupils were using simulations in pairs in the lesson, the teacher would walk around the room helping the pupils where needed. The teachers saw themselves in new roles as facilitators. However, this is exactly what most science teachers do in their laboratory classes, which was clearly not observed by the researchers.

7.9.3 Interviews with teachers

In order to find out more about the teachers' ICT skills and their pedagogical reasoning, it is possible to collect data by interviewing teachers, as has been the method used by researchers in many of the studies reported here. Our very brief case studies were able to find out what kinds of ICT uses teachers were engaged in and the pedagogical reasons behind these. However, the limitation of one interview per teacher means we did not know how this would change over time, nor what influence their ICT experiences might have on their pedagogical practices over a longer period. Ideally, in a research study, it is more reliable to interview teachers several times over an extended period in order to gather sufficient data to gain a comprehensive knowledge of the teachers' pedagogies.

Many researchers have also used interview techniques to find out what the ICT expertise of the teacher is, and therefore how this might influence their use of ICT in their teaching. However, our

case studies have shown that this is a very subjective assessment, because generally the more you know about ICT the more you know you do not know. Unless the researcher is aiming only at measuring teachers' perceptions of their ICT expertise, it is more effective to use measures which require teachers to demonstrate their ICT expertise, for example one of the many ICT tests such as the European Computer Driving Licence.

7.9.4 Teachers' and pupils' questionnaires

Large-scale questionnaire-based studies such as the annual DfEE/DfES surveys of schools (DFEE, 2000) have been used to collect data about the frequency of teachers' ICT use and confidence. Although such studies do give useful statistical data which show trends and the effects of government policies on the uptake of ICT use in schools, they do not really tell us much about teachers' pedagogical practices.

A good example of the limitations of such a method was the Teachers as Innovators project (Preston *et al.*, 2000) which surveyed over 100 ICT teachers and co-ordinators using a very long and detailed questionnaire. A major part of this questionnaire was about the teachers' perceptions of the value of ICT in their teaching, but the researchers also asked about what types of ICT teaching were used on a regular basis. The results showed that the vast majority of the teachers believed that ICT helped make their lessons more interesting, challenging and so on. But the data also showed that the only ICT used by the teachers more than once per month was word processing. Therefore the results actually showed that teachers thought that word processing made their lessons more interesting. The result may have been very different for modelling, simulations or use of the internet. It is therefore very important when using questionnaires that the meaning of ICT is carefully explained and that researchers gather data about specific uses of ICT, rather than 'ICT' which clearly means all things to all teachers.

Another limitation of questionnaires is their reliability, especially regarding information about ICT use in schools. However, questionnaires are a way of collecting information about teachers' use of different ICT resources, their backgrounds, training experience and so on. The data about use in lessons can be corroborated to some extent by collecting data from the pupils as well. Sometimes the data from the teachers is ambiguous and data from the pupils clarifies such ambiguities. For example, in the first Impact study, teachers recorded their uses of ICT in a range of ways, one of which was through questionnaires returned at the end of each term. Pupils were also asked to complete a report sheet on their use of ICT at the end of every week for two years. On analysing the data, at first it looked as though there were inconsistencies in the teachers' and pupils' information. Many primary school teachers reported using computers several times a week, while their pupils were only using them once or twice a term. On further examination the apparent contradiction arose from the fact that most of the primary school teachers only had one or two computers in their class, so in order that 32 pupils could all use the computer at some point, only a few used it in each lesson. This showed that collecting similar evidence through questionnaires from pupils about teachers' pedagogical practices gives important information about the effect of these practices on pupils' access and attainment.

7.9.5 Teachers' lesson materials and pupils' work

The evidence from the review has included researchers reporting on examples of pupils' work and products to show stages in their learning and achievement outcomes. With the use of different types of ICT resources this can provide evidence of pupils' understanding, reasoning and interpretations. It can also show what effect a particular pedagogical practice has had on attainment of a specific task or skill. For example, Nikolopoulou and Cox (1999) measured the effects of using data-handling software on pupils' ability to use Boolean logical reasoning for analysing data. In addition to evidence collected through many observations of lessons, they also collected evidence from teachers about their lesson plans as well as pupils' completed work. This enabled them to show a direct relationship between the methods the teachers were using to teach data handling, the pupils' interactions with the database package and the attainment of the pupils.

The most reliable and consistent evidence from the literature showing the effects of teachers' pedagogies on pupils' attainment has been that which included examining evidence of teachers' curriculum and lesson materials and pupils' class work.

7.9.6 Attainment tests

The use of tests to measure pupils' learning is discussed in detail in the related report on ICT and attainment (Cox and Abbott, 2004). We only refer to it here regarding teachers' pedagogies. As we have shown in this study there is a direct relationship between teachers' pedagogies, their types of ICT use and therefore pupils' attainment. Attainment tests can show these effects when there is a major change in the whole curriculum as a result of the use of ICT, even though individual teaching strategies may not have been measured. For example, Jeffery and Adarsh in the case studies had replaced the literacy hour with drama and interactive video production for all the pupils. They were measuring attainment through both the Key Stage 1 SATs and their own literacy level tests. The results showed an immense improvement in pupils' literacy skills beyond any previous group of similar pupils.

The different pedagogical practices reported above result in different ways of assessing pupils' attainment. These varied from assessing pupils' final written products, using literacy tests, grading the quality of the content, and so on, to assessing pedagogical practices through pupils' presentations. In this case the pupils' knowledge and attainment is measured through their presentation, oral and written skills. The different techniques reported by the case study teachers have significance for further research, which is discussed in the final section (Section 7.10).

7.9.7 Other research methods

There are many other research methods which have been used in previous studies to measure teachers' pedagogical skills, some of which are also used in other areas of educational research. These include:

- Teachers' diaries and weekly record keeping
- Repertory grids
- Filming of the class activities
- Focus groups (see Section 6)
- Interviews with pupils
- Recording pupils' explanations when using ICT

The most important guiding factor is to match the methods to the aims of the research and, in the case of assessing the effects of teachers' pedagogical uses of ICT on pupils' attainment, then this means measuring all the components and their related factors shown in Figure 5.5. The research discussed in this report has implications for further necessary research, and these implications are discussed in the final section below.

7.10 Priorities for future research

It is clear from this study that while there is now a substantial body of research into the uses of ICT in education and into teachers' pedagogical practices, there is still a long way to go before we can map more fully our understanding of the real relationships between teachers' uses of ICT, their pedagogical knowledge and the effects on pupils' attainment.

7.10.1 Long-term studies

Much research focuses on a specific impact of a specific use or intervention and during a particular time, such as the introduction of laptops into one group within a school. Unfortunately the evaluations are often ephemeral, that is we do not know enough about the long-term impact on classroom practice. Longer evaluations of impact after two to three years would give us more knowledge of the durability of the intervention. We do know that evaluations undertaken by the same team as those who engaged in the intervention can be useful in terms of action research and assessing the impact upon those individual teachers involved; they still do not tell us enough about durability. For there to be a long-term impact, the intervention and its value must become embedded in normal practice. In too many instances we have evidence that in one-off projects and interventions this is not the case.

7.10.2 The teacher and the learning context

The emphasis of policies and research has been on the use of ICT in the general context of schooling. Specific context has not been paid enough attention. Most of the research reported in

this study has shown that the greatest level of integration of specific ICT resources by teachers has been in very specific subject contexts. Thus we need more research investigating the effects of specific uses of ICT in specific subjects. Teachers in schools at all levels associate themselves with the particulars of their teaching styles and their pupils' learning. The particulars of learning are always contextualised within a frame, whether it is numeracy or geography, science or problem-solving, artistic expression or communication. Pupils learn within such frames. Research in the 1980s indicated substantial potential for ICT embedded in the curriculum, which has been confirmed in our very recent case studies. The recent reappearance of an emphasis on embeddedness should prove fertile ground for research. The emphasis on learning and information resources has led to less research on teaching with ICT, and engagement with the pedagogic context of learning has been neglected.

7.10.3 Teachers' pedagogical reasoning

The research reported in this study has shown how important teachers' pedagogical reasoning is regarding the ways in which they select and use ICT and how they integrate it into their teaching, yet very little research has been reported which measures the pedagogical reasoning of teachers over a period and how this affects their long-term use of different ICT resources. There is little evidence of the teaching practices outside the lessons which have a fundamental influence on the way ICT is used in the lesson. Substantial research is needed into teachers' pedagogical reasoning in relation to the subject context, in relation to the different pupil groups, in relation to their understanding of ICT itself and in relation to the long-term effects on pupils' attainment.

7.10.4 Effects on other teachers

Since the early 1980s, the impact on their colleagues of a teacher 'expert' in using ICT has been discussed, and there is evidence about teachers' ability to learn from their colleagues. What we have shown in this study is the important effect of teachers' pedagogical reasoning on how they use ICT in their teaching. Yet many teachers, especially ICT teachers, have the responsibility for teaching their colleagues how to use ICT in their teaching. An important unanswered question here is 'How do the pedagogical reasoning and practices in using ICT of one teacher affect other teachers' willingness and ability to integrate it into their teaching?'

7.10.5 Teachers' professional development

Finally the research reported in this study has shown that there is a continuing need for further professional development of teachers if they are to understand the value of ICT to their curriculum and their pupils. There have been many studies investigating the effects of teacher training on the uptake of ICT by teachers, but little is known about the relationship between their experiences of professional development and their subsequent pedagogies when using ICT. Therefore this relationship is an important topic for research, focusing on the models and content of teachers' professional development, including their formal and informal experiences and the impact which these have had on their pedagogical reasoning and consequent practices when using ICT.

7.10.6 Literature review

The literature review reported here has created a significant resource for teachers, researchers, governments and others involved in ICT in education. However, there are many other publications with further evidence about ICT in education which could not be used because of the limited scope of the project. An important additional study would be to produce an annotated bibliography of all the evidence presented here, augmented by further publications for other researchers to use as a knowledge base and springboard for new projects and policy decisions. In comparing this with many projects from the Economic and Social Research Council, the expected resource for such a study would be at least two person-years.

8 ICT pedagogy – final word

In this study we have identified a range of pedagogical practices which should be part of a teachers' pedagogical frameworks if they are going to be able to integrate ICT effectively into the curriculum and into teaching and learning:

- Teachers need to understand the relationship between a range of ICT resources and the detailed concepts, processes and skills in their subject.
- Teachers need to use their subject expertise to obtain and select appropriate ICT resources which will help them meet the pupils' learning objectives. This includes subject-specific software as well as more generic resources.
- Teachers need knowledge of the potential of ICT resources not only in terms of their contribution to pupils' presentation skills but in terms of their facilities for challenging pupils' thinking and extending pupils' learning in a subject.
- Teachers need confidence in using a range of ICT resources, which requires frequent practice and use of more than one or two types of ICT resource.
- Teachers need to understand that some uses of ICT will change the nature and representations of knowledge, and the way the subject is presented to and engages the pupils.
- Teachers need expertise in organising pupils when using ICT resources within the class. They need to know when pupils should work on their own, how working in pairs and groups should be organised and when to use ICT for whole-class teaching.
- Teachers need to know how to prepare and plan lessons where ICT is used which will challenge pupils' understanding and promote reflection and thinking.

Finally teachers need to know how to integrate ICT into their pedagogical practices to complement the other teaching and learning activities and improve pupils' attainment.

If we compare the evidence of teachers using ICT in schools 20 years ago and that obtained in 2003 from the hundreds of studies reported here, in spite of all the constraints and limitations the evidence shows that there is a steady growth in the number of innovative and experienced teachers able to use specific ICT resources to improve their pupils' attainment. What we need now is a way of helping the rest of the teachers and pupils benefit from these opportunities and experiences.

Appendix 1

Keywords

ACCESS	INNOVATION
ACHIEVEMENT	INTEGRATED LEARNING SYSTEMS
ADULT EDUCATION	INTERNET
AGE	LEAGUE TABLES
ART	LEARNING PROCESSES
ASSESSMENT	LIFELONG LEARNING
ATTAINMENT	LITERACY
ATTITUDES	MATHEMATICS
BARRIERS	MOBILE TECHNOLOGIES
BEHAVIOUR	MODERN FOREIGN LANGUAGES
CALCULATORS	MOTIVATION
CD-ROM	MUSIC
CLASSICS	ONLINE LEARNING
CLASSROOM PRACTICE	PEDAGOGIES
COGNITION	PHYSICAL EDUCATION
COMMUNICATION	PRIMARY
CONFIDENCE	PROBLEM SOLVING
CPD	PUPIL : COMPUTER RATIO
CREATIVITY	RELIGIOUS EDUCATION
DIFFERENTIATION	SCHOOL SETTINGS
DISTANCE LEARNING	SCIENCE
E-LEARNING	SECONDARY
ENGLISH	SKILLS
EPISTEMOLOGIES	SOCIAL CHARACTERISTICS
GEOGRAPHY	SPECIAL EDUCATIONAL NEEDS
HISTORY	TEACHING INTERVENTIONS
ICT	TEACHING METHODS
ICT ENVIRONMENTS	TEACHER EDUCATION
INCLUSION	WHOLE-CLASS TEACHING
INDIVIDUALISED LEARNING	
INFORMAL LEARNING	

Appendix 2

List of journals identified

ACM Transactions
American Educational Research Journal
Applied Linguistics
Assessment in Education
Association for Learning Technology Journal
Association for Science Education Bulletin
Australian Journal of Educational Technology
Biochemistry and Molecular Biology Education
British Education Index
British Educational Research Journal
British Journal of Educational Studies
British Journal of Educational Technology
British Journal of In-Service Education
British Journal of Sociology of Education
British Journal of Special Education
British Journal of Teacher Education
Changing English
Cite
Cognitive Psychology
Comparative Education
Computer Assisted Language Learning
Computer Education
Computer Networks for Research in Europe
Computer Physics Communications
Computer Supported Co-Operative Work
Computer
Computers and Composition
Computers and Education
Computers and the Humanities
Computers in the Schools
Curriculum Journal,
Des Report on Education
Education
Education and Computing
Education and Information Technologies
Education and Training
Education for Primary Care
Education for Teaching
Education in Chemistry
Education in Science
Education Index
Education Review
Education Today
Educational Communication and Technology
Educational Computing and Technology
Educational Media International
Educational Research
Educational Studies in Mathematics
Educational Technology Abstracts
Educational Technology Research and Development
Educational Technology Review
English for Specific Purposes
English in Education
English Today

European Journal of Education
European Journal of Science Education
European Journal of Special Needs Education
European Journal for the Learning of Mathematics
Gender and Education
General Education
Higher Education
Higher Education Review
Holdings
Human Computer Interaction
IEEE Transactions on Education
Independent Learning in Science Newsletter
Individualising Learning in Science
Information Technology in Teacher Education
Information, Communication and Society
Innovations in Teaching and Learning in Information and Computer Sciences
Instructional Science
International Education Review
International Journal of Computer Vision
International Journal of Educational Development
International Journal of Educational Research
International Journal of Mathematical Education in Science and Technology
International Journal of Science Education
International Review of Education
International Yearbook of Education
Internet and Higher Education
Issues in Education
Journal for Research in Mathematics Education
Journal of Biological Education
Journal of Chemical Education
Journal of Computer Assisted Learning
Journal of Computers in Mathematics and Science Teaching
Journal of Curriculum Studies
Journal of Education
Journal of Education for Teaching: International Research and Pedagogy
Journal of Education Policy
Journal of Educational Computing Research
Journal of Educational Resources in Computing
Journal of English for Academic Purposes
Journal of Environmental Education
Journal of General Education
Journal of Higher Education
Journal of Information Technology for Teacher Education
Journal of Mathematical Behaviour
Journal of Research on Computing in Education
Journal of Research on Technology in Education
Journal of Science and Mathematics Education in Southeast Asia
Journal of Science and Technology
Journal of Second Language Writing
Journal of Social Policy
Journal of Special Education
Journal of Teacher Education
Journal of the Philosophy of Education
Language and Education
Language Learning and Technology
Language Teaching
Language Teaching Research
Learning and Individual Differences
Learning and Instruction

Learning and Motivation
Linguistics and Education
Mathematical Education for Teaching
Mathematics in School
Mathematics Teacher
Mathematics Teaching
Media Education
Media in Education and Development
Multimedia Information and Technology
Nctm News Bulletin
New Research in Education
Pedagogy
Physics Education
Programmed Learning and Educational Technology
Psychology Learning & Teaching
Psychology of Learning and Motivation
Quarterly Journal of Education
Research in Education
Research in Post-Compulsory Education
Research in Science and Technological Education
Research in Science Education
Research Papers in Education
Research Strategies
Resources in Education
Review of Educational Research
Review of Research in Education
Scandinavian Journal of Educational Research
School Effectiveness and School Improvement
School Leadership and Management
School Science and Mathematics
School Technology
School Technology Bulletin
Science and Education
Science and Technology Abstracts
Science Education News
Science Education Newsletter
Science Education
Sixth Form Mathematics Bulletin
Social Policy and Administration
Social Science Journal
Social Science Research
Social Studies of Science
Sociology of Education Abstracts
Sociology of Education
Studies in Educational Evaluation
Studies in Linguistics and Language Learning
Studies in Science Education
Teacher Education
Teaching and Teacher Education
Teaching Children Mathematics
Teaching Mathematics and Its Applications
Technology in Society
Technology, Pedagogy and Education
The World of Learning
Times Educational Supplement
Trends in Education
West African Journal of Education
Westminster Studies in Education
World Yearbook of Education

Written Language and Literacy
Year Book of Education
Zentralblatt fur Didaktik der Mathematik (International Reviews on Mathematical Education)

Appendix 3

Prioritised list of journals for searching

ACM Transactions
American Educational Research Journal
Applied Linguistics
British Educational Research Journal
British Journal of Special Education
Changing English
Cite
Computer Assisted Language Learning
Computers and Education
Education and Information Technologies
Education in Chemistry
Education in Science
Educational Studies in Mathematics
English in Education
European Journal of Education
European Journal for the Learning of Mathematics
International Journal of Mathematical Education in Science and Technology
International Journal of Science Education
International Review of Education
Journal of Biological Education
Journal of Chemical Education
Journal of Computer Assisted Learning
Journal of Education Policy
Journal of Educational Computing Research
Journal of Information Technology for Teacher Education
Journal of Science and Mathematics Education in Southeast Asia
Research in Science and Technological Education
Research in Science Education
Review of Educational Research
Science and Education
Science Education News
Science Education Newsletter
Science Education
Studies in Science Education

Appendix 4

Methods of collating and categorising the literature evidence

The mechanism established for reviewing, collating and cataloguing items was based on the relevant fields provided in EndNote. These were:

- Author
- Year
- Publication name, eg name of journal
- Volume (where relevant)
- Issue (where relevant)
- Abstract
- Notes

Where an academic paper included an abstract, this was recorded in EndNote and extended to provide sufficient analysis and review of the paper in question. The notes written by the specific reviewer were aimed at providing conclusive comment about the context, value, reliability and importance of the evidence or theory in the document being reviewed.

The areas and types of studies for review included the following:

- The ways in which ICT has been used and the attainment outcomes at Key Stages 1–4.
- Specific studies of clearly defined uses of ICT for learning particular concepts, processes or skills.
- Meta-studies which have measured the large-scale impact of ICT on attainment.
- Research evidence relating to specific curriculum subjects.
- Research evidence relating to specific social characteristics, eg age, gender, class, ethnicity.
- Evidence relating to factors which might influence the learning outcomes, such as teachers' pedagogies, ICT environment, level of ICT resources etc.

The review also includes important categories of evidence and theories of ICT in education (see Appendices 1 and 2) including **but not confined to** statistical evidence, where provided, of:

- the effects of ICT on attainment
- the frequency and range of use of ICT in schools and the home
- differential access and use in relation to social characteristics
- the changing nature of ICT education resource provision
- qualitative studies and case studies of the use of ICT in different school settings and subjects
- the ways in which ICT use relates to the ICT resource and learners' attainment
- the different aspects of learning promoted by ICT use
- the use of ICT in informal settings
- attitudes of pupils towards ICT-linked innovation.

Theories developed in the literature were also used to inform the analysis. These included:

- theories of innovation and change
- theories of behaviour and attitudes towards ICT
- theories of the application of ICT to education.

Appendix 5

Interview procedure

Information to teachers prior to the interview

The following information was sent out to teachers before the interview to focus their thinking.

The purpose of this short-term small study of teachers is to try to provide some pointers to how and why ICT use improves attainment. The ImpaCT2 study showed that ICT use does improve attainment in some areas. We are looking at teachers whose pupils' attainment has improved alongside the increasing use of ICT with a view to finding out how the teachers use ICT, how they plan for its use and what knowledge skills and abilities they and their pupils need in order to make effective use of ICT.

Please be assured that all information will remain confidential to the research team.

We would like you to think about a particular lesson that you have taught where you felt that the use of ICT was effective in enabling pupils to learn and improved their attainment. We want to understand the thinking that went in to planning and teaching that lesson and the knowledge and beliefs that led to your decisions. In particular we are interested in:

- the learning objectives for the lesson
- the nature of the activities and the use of ICT and associated resources
- the purpose and role of ICT in helping to achieve the learning objectives for the lesson
- the role of the pupils in helping each other to achieve the learning objectives for the lesson
- your role as the teacher and your interactions with the role of ICT
- your knowledge of the pupils' knowledge, skills and abilities including their ICT capability that lead to your planning decisions
- what the pupils learned in the lesson and the evidence for their learning
- how your teaching of this topic is different using ICT than when you taught it previously without the ICT facilities.

It would be helpful if you could provide lesson plans, materials, assessment records etc as available to help us to understand the nature of the lesson.

In more general terms we would like to understand:

- how has your teaching changed with the use of ICT?
- what do you believe about the value and purpose of ICT in learning?
- what evidence have you that ICT improves attainment and learning? We need to collect from you a summary of this evidence and supporting documentation. This might include:
 - teachers' records of pupil assessment
 - GCSE, SAT, end-of-year exam results
 - Pupils' self-assessments.
- What are the constraints to the further development of your use of ICT in teaching and learning?

Interview pro forma

Teacher name:	Date:
School:	Tape number:
Interviewer:	Transcribed: Yes /No

Summary of interview (including any comments on any non-verbal information received):

Documents collected

Document ref no.	Document name	Document description	Teacher comments on document

Lesson discussed

Lesson theme:	Date:
Type of ICT used:	Class
	Year

Lesson observation pro forma (summary sheet)

Teacher name:	Date:
School:	Class:
Observer:	Year:
Lesson theme:	
Type of ICT used (including software details):	
Overall impression of lesson:	

Description or sketch of room layout:

Documents collected

Document ref no.	Document name	Document description	Teacher comments on document

Lesson observation pro forma (commentary sheet)

Teacher Name:	Date:
Observer:	

Time	Commentary

Appendix 6

Primary school case studies – schools' and teachers' backgrounds

<i>Teacher's Name</i>	<i>Background of the teacher's school</i>	<i>Teacher's ICT skills and experience</i>
Jeffery	<p>Jeffery's school is a small primary school in a town in the South East of England with children of different backgrounds and social groups, with about 26 per cent of the children having special needs. There are very few from ethnic minorities in the school. The school has undergone substantial changes over recent years, with a new headteacher, major structural changes and a large investment into ICT resources. The pupil:computer ratio for ICT is about 3:1 in a classroom. The initial computers in the school were PCs, but over two years ago the school purchased six Apple Macs with video software and a digital camera so they could produce video materials. Each classroom has a few computers in it, with a cluster of computers outside.</p> <p>One of the major uses of ICT in the school is to teach literacy, but not within a specified literacy hour. Jeffery, who is headteacher of the school, believes that the literacy hour stifles creativity and switches off many pupils. The year 4 class for the literacy work described here had five PCs and seven Apple Macs, and the purpose of the year-long activity was to make and edit video materials of plays produced by the pupils.</p>	<p>Jeffery, the headteacher, was very experienced in the use of ICT. He had used a range of ICT packages on both PCs and Apples and often provides workshops for other teachers in the LEA about the educational uses of ICT in primary schools. His interest and expertise in ICT was clearly shown through the uptake of ICT by other teachers in the school, and the innovative ways in which ICT was being used. Jeffery is on the LEA's primary heads ICT group.</p>
Adarsh	<p>Adarsh works in the same school as Jeffery (see above). She is deputy head of the school and has a keen interest in ICT.</p>	<p>Adarsh has confidence in using some ICT applications but does not regard herself as an expert of many years. Before coming to the school she had not used ICT much in her teaching, but now uses some applications regularly. For example, she uses word processing for several hours a week, desktop publishing, subject-specific software, CD-ROMs and the World Wide Web for about an hour each week, and spreadsheets and databases for about an hour each month.</p>

<i>Teacher's Name</i>	<i>Background of the teacher's school</i>	<i>Teacher's ICT skills and experience</i>
Beatrice	Beatrice works in an inner-city Roman Catholic co-educational primary school with 150 pupils. The school has places for 429 pupils and is seriously under-subscribed, but this gives it a lot of space, and it has a room dedicated to 12 PCs besides having two or three computers in each classroom. The school is situated in an area of high unemployment and 68.5 per cent of the children receive free school meals. Despite this its current academic performance is higher than both the local authority and the national averages, and has improved consistently over the last five years.	Beatrice has been teaching for 16 years and has been using ICT for the past 12 years. She is currently seconded for half time by the local authority to develop strategies for effective teaching and learning in local schools. For the other half she is a teacher of 5- to 7-year old children and co-ordinator for ICT in the school. She runs training in the use of ICT both for her own school and for other local schools.
Deborah	Deborah works in an inner-city Roman Catholic school, the same school as Beatrice (see above).	Deborah has been teaching for 27 years and has been using ICT for the past 20 years. She is head of the school with no timetabled teaching commitment. She teaches using ICT for several hours a week and is a confident and experienced user.
Diana	<p>Diana's school is a small, half-form-entry school in the home counties. It had acquired additional financial resources for ICT equipment at a time when the school was undergoing major rebuilding work. The foresighted headteacher recognised the potential of the situation and took the opportunity to network the whole school, to standardise the equipment in terms of hardware and software, and to house all the hardware on trolleys to ensure maximum flexibility of resources. Teachers have access to projectors and an interactive whiteboard throughout the school, but the long-term objective is to have such equipment housed permanently within each classroom.</p> <p>Eight computers are housed in a computer suite which can be accessed by groups of children. The other machines are distributed in classrooms throughout the school. All teachers have a laptop computer. The school is fortunate to have a school-based trainee teacher who provides necessary technical</p>	<p>Diana, who is the school's ICT co-ordinator, teaches a mixed class of reception and year 1 children. She has had access to a laptop computer for about 18 months, and as she has grown in confidence her use of computers in the classroom has increased, particularly over the last six months. She feels, however, that her confidence will continue to develop with experience and further training.</p> <p>Diana is fortunate to have the support of two full-time learning support assistants, which enables her often to work with groups of children, usually half the class, in the computer suite, which is in easy reach of her classroom. Children work either individually or in pairs, although working in pairs is seen as being particularly valuable because the children instinctively take turns and help each other. A demonstration of programs to the whole class using the interactive whiteboard is regarded as valuable in instructing the whole class prior to individual or</p>

<i>Teacher's Name</i>	<i>Background of the teacher's school</i>	<i>Teacher's ICT skills and experience</i>
	<p>backup and has a keen personal interest in developing the use of the technology within teaching and within the broader community by running parents' classes. It was clear that the headteacher believed that computers had an important role to play in education although, possibly because computer use had only recently become established, there was no hard evidence to indicate that computers had had an impact upon attainment.</p>	<p>paired work. One of the advantages of computer technology noted by Diana is the interactivity of the medium with its graphics and 'all-singing, all-dancing' formats.</p>
Annabel	Annabel works in the same small school as Diana (see above).	<p>Annabel, who is the literacy co-ordinator, teaches a mixed class of 25 year 5 and 6 children for literacy. She is an experienced teacher who has, in the past, taught English in a secondary school. Although she has used computers in the past, it was only in the last few months that the technology has had an impact on her teaching. Prior to this the main use of computers in literacy had been for children to produce a final copy of hand-written work. She had recently decided, however, to take the technology on board and 'jump in at the deep end'.</p>
Carol	<p>Carol's school is a two-form-entry primary school with 15 classes. The school has 17 computers in a computer suite as well as five computers in each year group, two in each classroom and one in the corridor area outside. They are all networked. There are three mobile overhead projectors as well as one permanently in the ICT suite.</p> <p>All lesson planning is done electronically by year group teams of teachers, and the plans are saved in planning folders on the network server. The previous year's weekly plans are modified as necessary, in the light of the previous year's assessments of lessons and in order to meet the changing needs of the particular classes in each year group. These plans are available to everyone in the school so that the headteacher, for example, can see what is being taught in each area at any</p>	<p>Carol is the school's ICT manager. She teaches a class of foundation stage children. She had previously worked as an advisory teacher for ICT so she is very aware of what educational software is available and of the ways ICT can be used.</p>

Teacher's Name	Background of the teacher's school	Teacher's ICT skills and experience
	time. This has made planning far quicker than used to be the case. Teachers also have laptop computers.	
Louise	Louise's school is a one-form-entry primary school. There is a stand-alone computer in each classroom. There is also a bank of laptop computers housed permanently in the library which are suitable for whole classes with children working in pairs. The school has consistently good SAT scores for children in Key Stages 1 and 2.	While Louise is an experienced teacher she has only been using computers in her teaching for the last four to five years. She is deputy headteacher and literacy co-ordinator and teaches a class of 36 year 6 children. She does not consider herself an expert in computer use and believes that she needs to improve on her ICT skills, although time to develop such skills was perceived to be a problem.
Mary	Mary's school is a one-form-entry primary school. The headteacher has long been convinced of the value of computers in primary education and the school is well resourced. Each class has its own bank of several computers in the classroom. Interactive whiteboards have been gradually introduced throughout the school to all classes from year 6 initially down to year 2. All teachers using the whiteboards receive training in their use.	<p>Mary teaches a class of year 2 children. She co-ordinates Key Stage 1 and special educational needs. She has been teaching for almost five years and had used ICT in her teaching all that time. She has three computers in her classroom which are used throughout the week. She has recently had an interactive whiteboard fitted into her classroom, and although she was apprehensive about it initially, she is now using it 'all day, every day'. She has found that this technology has greatly enhanced her teaching as she has been able to access materials easily from the internet for the children, and has had a range of useful resources at her fingertips. She is confident in using the hardware and software available to her and satisfied with the level of resources within her classroom.</p> <p>The Key Stage 1 children now have a commercially produced scheme of work for ICT, where they learn ICT skills, which Mary found of value. She also used ICT across the curriculum where relevant. Each child now has an ICT file where their skills are recorded.</p>

Appendix 7

Secondary school case studies – school and teacher backgrounds

<i>Teacher's Name</i>	<i>Background of the teacher's school</i>	<i>Teacher's ICT skills and experience</i>
Adrian	<p>Adrian works in a secondary school situated on the edge of a small city. It is an 11–16 mixed foundation school with over 1,000 pupils. It has been a specialist technology college since 1995 and was designated a 'beacon school' in 1999. Adrian teaches in a modern laboratory which has 15 bench spaces each equipped with two flat-screen PCs.</p>	<p>Adrian is 38 years old and has been teaching for six years. He is the Key Stage 3 science co-ordinator and head of year 10. He has been using ICT throughout his teaching career. He uses an interactive whiteboard every day and a computer projector for several hours a week. He uses computers with pupils in lessons for several hours each week. In those lessons pupils use mainly presentation software and the internet. Homework is sometimes set requiring a computer so those without a computer at home have access to school computer facilities at breaks and after school. Adrian believes in thorough preparation for lessons using technology, doing all the internet research tasks (which he sets his pupils) prior to the lesson and providing them with a framework within which to work.</p>
Charlotte	<p>Charlotte works in the music department of a comprehensive school situated in the suburbs of a large city. The school achieves examination results roughly in line with the national average but considerably better than the local authority average. She considers the pupils to be "absolutely charming". On the other hand the head of ICT remarks that "we've got a number of pupils from really quite deprived backgrounds' who are 'extremely challenging".</p> <p>The school runs discrete courses in ICT, but not in the first year, though there are plans to begin doing so soon. This is because "the knowledge they come up with from the different primary schools is so diverse" and "also because of their experience at home."</p>	<p>Charlotte is an enthusiastic, energetic, highly experienced principal teacher with a career covering 25 years, some of which has been in consultancy, and has been using ICT for 13 of those years. Charlotte uses ICT extensively in her work. She has an interactive whiteboard with a computer data projector in her classroom that is used every day. She also makes daily use of music software, email and the World Wide Web with frequent use of word processing, desktop publishing and art/graphics software. She works in a room with 20 electronic music keyboards and eight PCs running a variety of music CD-ROMs and composition software. Her pupils are also able to make daily use of a computer suite where there is the facility for one computer per pupil.</p>

<i>Teacher's Name</i>	<i>Background of the teacher's school</i>	<i>Teacher's ICT skills and experience</i>
Eric	Eric works in a co-educational secondary school situated on the edge of a small city. It is an 11–16 mixed foundation school with over 1000 pupils. It has been a specialist technology college since 1995 and was designated a 'beacon school' in 1999. He teaches in a dedicated mathematics room which has tables grouped to form a large rectangle in the middle of the room and 14 computers around the outside of the room.	Eric has been teaching for 11 years, during nine of which he has been using ICT. He is second in charge of mathematics in the school and teaches the subject to years 7 to 11 and ICT to Key Stage 3. He uses subject-specific software and an interactive whiteboard with a computer data projector every day in his teaching.
Frank	Frank is a science teacher in an independent co-educational city technical college with more than 1,300 students, in the suburbs of a large city. From being a failing secondary modern school, in the last 13 years the school has been transformed into a successful college. Examination results have shown steady improvement over that period. This comprehensive school competes with selective grammar schools for its intake of pupils.	Frank is 50, has been teaching for 20 years and has used ICT in his teaching for the last five years. He teaches science to Key Stages 3, 4 and 5, including GNVQ. He uses mainly subject-specific software and the internet in lessons for several hours each week. He has limited access to an interactive whiteboard and a computer in his laboratory, and only occasionally uses a computer suite with one computer per pupil. He feels that the use of ICT makes his lessons more diverse and interesting for both himself and the pupils. He finds it makes explanations of difficult scientific theories and concepts easier. The main disadvantage is that ICT is not always available when he would like to use it.
Gwyneth	Gwyneth is a business studies teacher in a beacon school which has the use of ICT as one of its main areas of interest. It is an 11–18 co-educational comprehensive school of around 1,400 pupils, situated in the centre of a small town in the north of England. She works mainly in a dedicated business studies room equipped with 29 PCs and an electronic whiteboard suitable for use with marker pens.	Gwyneth is in her 40s and has been teaching in the school for the whole of her career, the last 24 years. She has always taught business studies so her involvement with ICT has come with the job. As ICT developed, so it became incorporated in her teaching.
Henry	Henry is a leisure, recreation, travel and tourism teacher in the same school as Gwyneth (see above). He works mainly in a dedicated room equipped with 20 PCs and an electronic whiteboard suitable for use with marker pens.	Henry is 50, has been teaching for 29 years, and has been using ICT in his teaching for the last 13 years. He used to teach geography but is now the teacher in charge of leisure and tourism courses, so his involvement with ICT has been an integral part of the job of teaching that subject for about 10

<i>Teacher's Name</i>	<i>Background of the teacher's school</i>	<i>Teacher's ICT skills and experience</i>
		years now.
Hazel	<p>Hazel's school is a large five-form-entry selective grammar school in the South East of England. The school has two computer suites which are used to deliver the ICT curriculum, but which can be booked by teachers in other faculties. The school also has an open-access computer area where pupils can go to work within lesson times, at lunch times and before and after school. The school has a pupil:computer ratio of 4.5:1.</p> <p>Children's ICT capability is assessed in year 7 and their level of ability recorded and monitored as they move up the school. They are also taught at this stage how to search the internet effectively, a skill which is revisited when they reach year 12.</p> <p>The use of ICT within subject areas is variable and dependent on the individual teacher's experience, confidence and interest. However some departments deliver specific aspects of the ICT curriculum, for instance the use of presentation software in geography to give a presentation of their work, multimedia in English to develop and promote reading schemes for younger children, and modelling and spreadsheets in mathematics.</p> <p>There is an ICT representative in each form, as well as an ICT officer and two ICT prefects who help support the ICT co-ordinator by, for example, helping with the publication of documents.</p> <p>The school has good academic results with, for example, pupils achieving well above the national average in English, mathematics and science at the end of Key Stage 3 and with 99.2 per cent of pupils gaining A*– C grades in GCSE</p>	<p>Hazel is an experienced teacher who has taught at the school for over 20 years. She is currently the ICT co-ordinator, although she has taught other subjects in the past.</p> <p>Although she teaches ICT as a subject, she is aware that the pupils are learning skills that they can then apply across the curriculum. The technology should, in her opinion, be considered as a learning resource, hence the open-access policy. She believes, however, that within subject areas ICT should be used by teachers to enhance and enrich the curriculum they are teaching rather than for its own sake.</p> <p>ICT is taught by Hazel and a colleague to small groups of up to 14 pupils. The girls work together in pairs of similar ability chosen by the teacher because it is believed that they will work well together, have the same level of understanding of the task in hand and be able to discuss things.</p>

<i>Teacher's Name</i>	<i>Background of the teacher's school</i>	<i>Teacher's ICT skills and experience</i>
	<p>examinations in 2001–02. All pupils are expected to study for nine subjects at GCSE in year 11, four AS subjects in year 12 and three A-levels in year 13.</p>	
Lorna	<p>Lorna works in the same school as Hazel, which is a large five-form-entry selective grammar school. See above.</p>	<p>Lorna is head of the modern foreign languages faculty. She has only been teaching at the school for six months, having previously taught in mixed comprehensive schools. She first became interested in developing the use of technology in her teaching four years ago when teaching at a city technology college. She established a working link with a nearby language college which had developed some innovative uses of ICT. She then began to develop the use of the technology within her own department, establishing three suites of 15 computers and introducing a lot of language-related software and a variety of ICT equipment.</p> <p>Experience had shown her that technology is a “very effective” tool in teaching. However, she is aware that as a tool ICT should fit into schemes of work in order to meet the “differentiated requirements that you need to underpin” in teaching by providing “pace and variety to motivate young people.”</p>
Breeda	<p>Breeda works in the same school as Lorna and Hazel – a large five-form-entry selective grammar school. See above.</p>	<p>Breeda is head of the geography department. ICT is used in a variety of ways throughout the department.</p>
Jonathan	<p>Jonathan is head of geography and an advanced skills teacher in a technology college. The school is an 11–18 co-educational comprehensive school of about 1,400 students, situated on the edge of a town. The school has several ICT suites and good internet access. A few rooms are equipped with an interactive whiteboard. Teachers are able to place documents for students' use on the school intranet. This intranet facility is being</p>	<p>Jonathan is 42, has been teaching for 19 years, and has been using ICT in teaching for the last five years. Jonathan is fairly satisfied with the level of ICT resources available to him and finds it easy to think of ways to use ICT in his teaching. Jonathan is experienced in using a wide range of software, but makes most use of CD-ROMs and the World Wide Web for providing students with access to resources, in particular</p>

Teacher's Name	Background of the teacher's school	Teacher's ICT skills and experience
	developed to make a more useful system that students can access from home as well as school, and to enable documents to be organised and accessed in a more efficient way.	geographical images.
Robert	Robert is an advanced skills teacher of biology in the same school as Jonathan. See above.	Robert is 38, has been teaching for eight years, and has been using ICT since he first started teaching. He uses a full range of software in his teaching on an occasional basis, ie for about an hour each month, but he makes greater use (at least an hour each day) of graphics software, modelling software and some subject-specific software. Robert has an interactive whiteboard in his main teaching room and uses it regularly.
Aloysius	Aloysius is a teacher of geology and science in a technology college – the same school as Jonathan and Robert. See above.	Aloysius is 37, has been teaching for four years, and has been using ICT since he first started teaching. During his initial teacher education Aloysius was encouraged to make significant use of ICT, and he felt that he had a good introduction to the use of ICT in teaching. Aloysius uses the internet for about an hour each week in his lessons, but expects his students to use the resources he has prepared on the internet for several hours a week. He also uses spreadsheets, databases, modelling software, and measurement and control software occasionally (for about an hour each month) in his teaching. Aloysius spends much time preparing web-based material for his students by selecting and integrating material that he finds from the internet.
June	June is a specialist ICT teacher in the same technology college as Jonathan, Robert and Aloysius. See above.	June is 34, and has been teaching for eight years and making use of ICT in her teaching during all that time. She has recently taken on the role of cross-curricular ICT co-ordinator. June's current priority is to develop the school's intranet to enable teachers to provide resources that can be accessed by students and parents at home as well as at school. June sees the intranet as essential to allow staff and students to use ICT

<i>Teacher's Name</i>	<i>Background of the teacher's school</i>	<i>Teacher's ICT skills and experience</i>
		effectively. Key people from each department or faculty are responsible for keeping and maintaining the departmental area on the intranet.
Gordon	Gordon is a science teacher specialising in chemistry and with senior management responsibilities. His school is an 11–19 co-educational comprehensive school of around 2,000 students situated in a suburb of a major city. There are ICT suites available that Gordon is able to book for about one hour per week, and he is also able to book a data projector for approximately one hour per week.	Gordon is 49, has been teaching for 22 years, and has been using ICT for 20 years. He uses a wide range of software including word processing, spreadsheets, databases, modelling software, measurement and control software, but it is only the internet that he uses very regularly in his teaching (about an hour a week).
Sajeda	Sajeda is a chemistry teacher who joined the school in which Gordon (see above) works in January. At her previous school she had better access to ICT resources and feels a little frustrated in this school where the level of resourcing is improving but is not up to the level she was used to.	Sajeda is 29, has been teaching for six years and has been using ICT in her teaching for four years. She uses word processing, spreadsheets, databases, measurement and control software, subject-specific software, email and the internet in her teaching, but she is generally only able to use each for about an hour each month. The exceptions are email and the internet, which she uses for about an hour each week.
Suzanne	Suzanne teaches art and design in the same 11–19 co-educational comprehensive school as Gordon and Sajeeda. See above.	Suzanne uses a range of software that is relevant to art, including various painting packages, desktop publishing programs, animation software and the internet. Her ICT experience is greatest with these applications.

Appendix 8

ICT in TEACHING questionnaire

This questionnaire is to collect data about your ICT uses in teaching as part of the British Education and Communications Technology Agency (Becta) project on ICT and eachers' pedagogies

NB All information in this questionnaire will remain confidential to the research team.

Alternatively you can print it out and fill it in by hand and give it to the researcher who will be visiting your school in the next week or so, or return by post – see address at the end.

1 Personal Information

1.1 Name:			
1.2. Age:		1.3. Sex:	M / F
1.4. Contact address:			
1.5. Telephone number:			
1.6. Fax number:			
1.7. Email address:			
1.8. Name of institution:			
1.9. Job title:			
1.10. Outline of current teaching commitments:			

2 Your teaching experience

2.1 Number of years of teaching:		2.2 Number of years of using ICT in teaching:	
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3 How often you use ICT with pupils for teaching and learning?

Please answer each of the following questions by circling or highlighting the appropriate response.

	never	about an hour each month	about an hour each week	several hours a week	more than an hour a day
3.1 Word processing	1	2	3	4	5
3.2 Spreadsheets	1	2	3	4	5
3.3 Databases	1	2	3	4	5
3.4 Desktop publishing	1	2	3	4	5
3.5 Art/graphics software	1	2	3	4	5
3.6 Modelling software	1	2	3	4	5
3.7 Measurement and control	1	2	3	4	5
3.8 Subject-specific software	1	2	3	4	5
3.9 Email	1	2	3	4	5
3.10 World Wide Web	1	2	3	4	5
3.11 Computer data projector	1	2	3	4	5
3.12 Suite with 1 computer per pupil	1	2	3	4	5
3.13 Suite with 1 computer per 2 or 3 pupils	1	2	3	4	5
3.14 Classroom with one computer	1	2	3	4	5
3.15 Laptop computers: one per pupil	1	2	3	4	5
3.16 Laptop computers for group(s) within class	1	2	3	4	5
3.17 Cluster of desktop computers in or near classroom	1	2	3	4	5
3.18 Interactive whiteboard	1	2	3	4	5
3.19 Creating and editing video	1	2	3	4	5
3.20 Rotated tasks: some incorporating ICT use	1	2	3	4	5

3.21 Sending pupils to remote computer facility during lesson	1	2	3	4	5
3.22 Setting computer-based homework	1	2	3	4	5

4 Using ICT in your teaching

Please answer each of the following questions by circling or highlighting the appropriate response.

4.1–4.3 The ease of using ICT in your lessons

	strongly disagree	disagree	neutral	agree	strongly agree
4.1 I find it easy to think of ways to use ICT in my teaching	1	2	3	4	5
4.2 I often have difficulties using software/hardware	1	2	3	4	5
4.3 I am satisfied with the level of ICT resources available to me	1	2	4	4	5

4.4–4.16 The advantages and disadvantages of using ICT in your lessons

ICT:	strongly disagree	disagree	neutral	agree	strongly agree
4.4 makes my lessons more interesting for me	1	2	3	4	5
4.5 makes my lessons more difficult for me	1	2	3	4	5
4.6 makes my lessons more diverse	1	2	3	4	5
4.7 reduces pupils' motivation	1	2	3	4	5
4.8 has improved the presentation of material in my lessons	1	2	3	4	5
4.9 makes preparing for lessons more time-consuming	1	2	3	4	5
4.10 restricts the content of my lessons	1	2	3	4	5
4.11 makes preparing for lessons more difficult	1	2	3	4	5
4.12 makes the lessons more fun for the pupils	1	2	3	4	5
4.13 makes it more difficult to control the class	1	2	3	4	5
4.14 has often disrupted my lessons due to problems with hardware/software	1	2	3	4	5
4.15 has given me more confidence to extend my use of computers to other topics	1	2	3	4	5
4.16 has given me greater awareness of its uses	1	2	3	4	5

4.17 What do you feel are the main advantages of using ICT in your teaching?

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4.18 What do you feel are the main disadvantages of using ICT in your teaching?

Thank you for your time and help with our research.

Appendix 9

Focus Group Meeting 28th April 2003

Purpose

To clarify perceptions of teachers of the value of ICT in learning and teaching

To clarify perceptions of teachers of the range of pedagogies and practices they employ associated with the use of ICT in learning and teaching

To identify issues affecting their use of ICT in learning and teaching

Goals

To find out:

teachers' reasons for using ICT

- teachers' beliefs about how children learn
- teachers' perceptions of the range of ways in which ICT can be used to support learning and teaching effectively
- the perceived benefits of use of ICT
- how particular types of ICT use and methods of using them are perceived to influence learning
- how ICT has affected their teaching
- the effects of their ICT skills on their use of ICT
- the factors that facilitate/inhibit the use of ICT

Questions

- What were your own reasons for using ICT with your pupils?
- Present a list of ways of using ICT and types of ICT use that have emerged from the school study (see below) and ask each of them to comment on one that they consider to be particularly useful. They may want to refer to particular examples. Things to think about are:
 - How do pupils learn in this situation?
 - What types of knowledge, skills or abilities are best developed through this type of use?
 - What types of ICT use are we thinking about?
 - What is the role of the teacher?
 - Does the role of the teacher depend upon the type of ICT being used?
 - What is the role of the pupils?
 - Do you think you have any evidence that pupils learn better when using ICT in particular ways?
 - What skills and knowledge does the teacher need?
 - What skills and knowledge do pupils need?
- Are there specific types of ICT which you think are more important for pupils than others?
- Are there any important ways of using ICT that we should add to the list?
- How has the use of ICT changed learning and teaching for you and your pupils?
- How do you expect the use of ICT to change learning and teaching for you and your pupils in future?
- What are the main barriers for you in using ICT?
- What factors facilitate your use of ICT?

Types of ICT use

1. In small groups pupils role-play a story or episode from fact or fiction which they video. They then edit the video to produce a film or multimedia presentation, for a particular audience.

2. The whole class brainstorms about a topic to produce a mind map on the interactive whiteboard.
3. Pupils use a modelling environment to challenge their own misconceptions and build steps in a model.
4. The teacher leads a question-and-answer session with the whole class based on a simulation, animation or problem-solving activity on the interactive whiteboard.
5. Pupils work at a cluster of computers in the classroom on an art, design data-logging or problem-solving task that focuses on some specific learning objectives for the current topic, while the rest of the class work on other activities.
6. Pupils work collaboratively in groups during lessons to research a topic from the web, obtain material and develop a multimedia presentation, poster, or newspaper.
7. The teacher develops a web-based multimedia resource that functions as a set of notes and learning activities. The teacher refers to it in the lesson and sets homework based on the resource.
8. Pupils work individually to research a topic from an internet, intranet or CD-ROM-based resource prepared or selected by the teacher and produce notes or answers to specific questions.
9. Pupils research a topic individually by conducting their own web searches and making notes.
10. Pupils construct models to investigate the relationship between variables in a process.
11. Pupils search a specialised database to find answers to questions.