ICT in Schools Research and Evaluation Series – No.18

ICT and pedagogy

A review of the research literature

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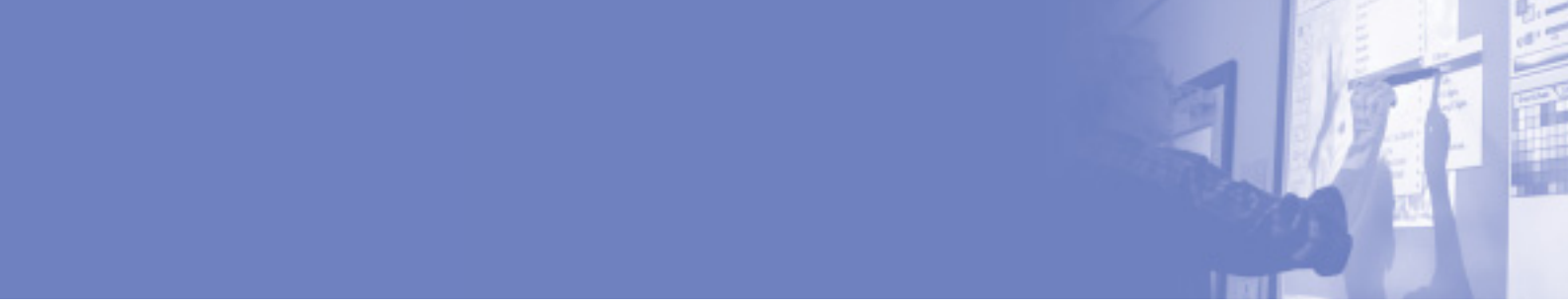


Contents

ICT and pedagogy

Executive summary

The evidence from the research literature shows that teachers' pedagogies and pedagogical reasoning influence their uses of ICT and thereby pupils' attainment.

Teachers' subject knowledge

The way ICT is used in lessons is influenced by the teachers' knowledge about their subject and how ICT is related to it. Some teachers choose ICT resources that relate to a particular topic, while others use ICT 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 understood the subject, their use of ICT has a more direct effect on pupils' attainment. The effect on attainment is greatest when pupils are challenged to think and to question their own understanding, either through pupils using topic-focused 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.

Teachers' pedagogical knowledge

The teacher's own pedagogical beliefs and values play an important part in shaping technology-mediated learning opportunities. It is not yet clear from the research literature whether this results in technology being used as a 'servant' to reinforce existing teaching approaches, or as a 'partner' to change the way teachers and pupils interact with each other and with the tasks. Teachers need extensive knowledge of ICT to be able to select the most appropriate resources. They also need to understand how to incorporate the use of ICT into their lessons; they may need to develop new pedagogies to achieve this.

Pedagogical practices of the teacher using ICT

The pedagogical practices of teachers using ICT can range from only small enhancements of practices using what are essentially traditional methods, to more fundamental changes in their approach to teaching. For example, some teachers using an interactive whiteboard have displayed content and ideas for class discussions in a traditional way, while other teachers have allowed pupils to use the whiteboard to present dramas to the whole class that they had planned and filmed themselves.

Studies 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 an interactive 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 both whole-class and individual work can be equally effective.

Access to ICT resources

An important influence on the use made of ICT in subjects and classes is the amount and range of ICT resources available to the teachers. Where there are limited numbers of computers in a class, mostly in primary schools, this limits their impact, because each individual pupil is only able to use the computer for a few minutes.

Whole-class use of an electronic whiteboard has both positive and negative effects. It promotes pupils' debates and helps them visualise difficult concepts and processes. However, some teachers focus only on the presentation aspects, disregarding the use of simulations and modelling which might be more challenging for the pupils. Only a few teachers report using subject-specific software which links directly to the content and purpose of the curriculum.

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.

Teachers' confidence in using ICT

Teachers are confident in their chosen uses of ICT. 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 some forms of technology, which prevents them making much use of them in their teaching.

Organisation

The use of ICT has a limited impact on teaching and learning where teachers fail to appreciate that interactivity

ICT and pedagogy

requires a new approach to pedagogy, lesson planning and the curriculum. Some teachers reorganise the delivery of the curriculum, but the majority use ICT to add to or enhance their existing practices. Teachers need to employ proactive and responsive strategies in order to guide, facilitate and support 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 teachers to gather extensive feedback from pupils by listening to their explanations. From this, teachers are able to gain deeper insights into pupils' understanding and progress. Pupils collaborating in pairs or teams using subject-specific ICT resources are able to challenge each other's understanding and learn from such collaborations.

Pedagogy beyond the classroom

Despite the need for a new pedagogy with ICT, including at times moving to a facilitator role, teachers still need to adopt a leadership role in the planning, preparation and follow-up of lessons. Where little planning has occurred, the evidence shows that the pupils' class work is unfocused and leads to less than satisfactory outcomes.

Effects of pedagogical practices on pupils' attainment

There is extensive evidence of ICT contributing to pupils' attainment (see for example the companion publication to this literature review (Cox and Abbott, 2004)). However, the evidence shows that these benefits depend on the way in which the teacher selects and organises ICT resources, and how this use is integrated into other activities in the classroom and beyond.

At present, the types of ICT resources available mean that ICT use is nearly always focused on specific aspects of the curriculum. There are two clear areas where teachers have been shown to embed ICT in their teaching, and where this has enhanced learning; these are in:

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

Effective pedagogical practices with ICT

This literature review has identified a range of practices which should be part of teachers' pedagogical frameworks if they are to integrate ICT effectively into teaching, learning and the curriculum. These include the need for teachers to:

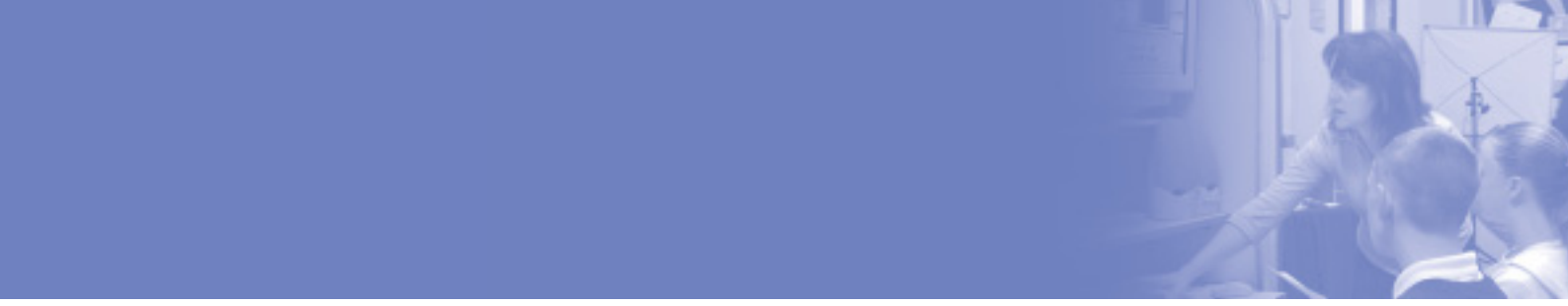
- understand the relationship between a range of ICT resources and the concepts, processes and skills in their subject
- use their subject expertise to select appropriate ICT resources which will help them meet the specific learning objectives; this includes subject-specific software as well as more generic resources
- be aware of the potential of ICT resources both in terms of their contribution to pupils' presentation skills, and their role in challenging pupils' thinking and extending their learning in a subject
- develop confidence in using a range of ICT resources, via frequent practice and use beyond one or two familiar applications
- appreciate that some uses of ICT will change the ways in which knowledge is represented, and the way the subject is presented to and engages pupils
- know how to prepare and plan lessons where ICT is used in ways which will challenge pupils' understanding and promote greater thinking and reflection
- recognise which kinds of class organisation will be most effective for particular learning tasks with ICT, for example, 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.

The majority of teachers, including the most innovative, require more knowledge of and confidence with ICT, and a better understanding of its potential to help pupils' learning. This suggests that further substantial support for continuing professional development is necessary in order that teachers integrate the use of ICT and improve pupils' attainment.

Background and further reading

This literature review is published alongside a companion literature review on the impact of ICT on attainment (Cox and Abbott, 2004). The reports complement each other and serve to provide a foundation in understanding the research literature on ICT, attainment and pedagogy.

The full report on which this publication is based is available on the Becta Research website [www.becta.org.uk/research/].



Introduction

Background to the study

This study 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 study aims to address the following questions:

- a review of the existing literature on ICT pedagogy, in order to identify how ICT can have some impact on attainment, through studying aspects of the ways in which ICT is used, and the accompanying actions of teachers
- 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.

The study aimed to addess the following questions:

- What are teachers' pedagogies?
- What is the relationship between different types of ICT use and teachers' pedagogical practices?
- What types of hardware, software and communications are being used by teachers and for what purposes?
- In what ways has ICT been integrated with other more traditional teaching methods?
- What are the levels of use of ICT in schools for different types of ICT?
- 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?

Approach to the literature review

The study involved collecting data from various sources, published in the English language from 1990 to the present day (with the exception of a few key sources), including quantitative surveys and statistical publications, qualitative or case study data and previously published meta-analyses (studies which aggregate the findings from many other studies). The emphasis was on identifying work that was both original and nationally important. Additional attention was also given to the variables considered and the applicability of results.

The areas and types of studies for review included:

- the ways in which ICT has been used and the attainment outcomes for 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, for example, age, gender, class and ethnicity
- evidence relating to factors which might influence the learning outcomes, such as teachers' pedagogies, the environment in which ICT is used, and level of ICT resources.

Approach to the case studies

The short case studies involved 26 teachers who are already known to be using ICT effectively to support attainment, drawn 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 compared with other classes in the school
- Quality of pupils' work compared with the achievements of pupils in previous years.

A more detailed account of the procedures and sources used can be found in the full report on which this publication is based, available on the Becta Research website [www.becta.org.uk/research/].

This study is one of two literature reviews, commissioned as part of the ICT and Attainment project. The other review (Cox and Abbott, 2004) considers the research evidence relating to the impact of ICT on attainment. 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. The reports complement each other and serve to provide a

foundation in understanding the research literature on ICT attainment and pedagogy.

It was not possible within the time-scale of the project to review all the published evidence. However, in order to utilise the evidence from this broader literature the project team produced two literature bases. The first is a list of references to which this report specifically refers, which are included in this publication. These include a wide range of empirical findings and theoretical perspectives. The second is a wider bibliography which has informed and underpinned the approach and analysis. This is available along with the full version of this report on the Becta Research website [www.becta.org.uk/research/].

The project team

Editor and project director – Margaret Cox
Study editors – Chris Abbott and Mary Webb
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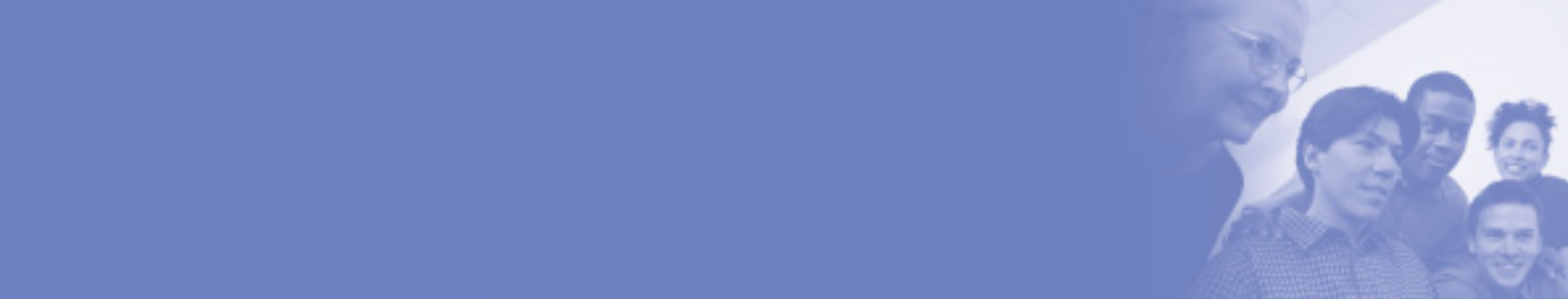
Acknowledgements

The project team wishes to acknowledge the support of Becta and the DfES for initiating and funding the two projects reviewing the literature into ICT and attainment and ICT pedagogy, and also acknowledge the ongoing advice, encouragement and support received, in particular from Malcolm Hunt, Head of Evidence and Research, Becta, and from Andrew Jones and Michael Harris, Education Officers, Becta.

The team would also like to acknowledge the support and advice from academic and administrative colleagues at King's College London and also at the University of Leeds. Finally the team would like to thank all the teachers and schools who participated in the study into ICT pedagogy, who gave their time willingly and freely and who provided exciting examples of innovative uses of ICT in their teaching.



Section 1 Theories of pedagogy

This section presents a discussion of different pedagogical perspectives and theories derived from the literature review. There is clear evidence that teachers' perceptions of pedagogy relating to ICT are often confined to classroom practice. This section provides a broader base for understanding what pedagogy involves and how this might apply to the use of ICT in teaching. For a more extensive review of pedagogy see Webb (2002).

What is pedagogy?

Watkins and Mortimore (1999), in a review of research literature on pedagogy, assert that the models of pedagogy held by researchers and academics have become more complex over time, incorporating, for example, recent developments in our understanding of cognition and meta-cognition.[1]

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 1.1) where pedagogy is one of seven interrelated aspects (Alexander describes the dimensions of his framework as a minimum list rather than a fully comprehensive framework).

This suggests that the pedagogy of ICT should be understood within a broader framework of educational practice. What is observed in the classroom is only part of this practice. Thus, illuminating good practice in teaching and learning with ICT will require examining teachers' ideas, values, beliefs, and the thinking that leads to observable elements in practice.

Pedagogical reasoning

The processes of planning, teaching, assessing and evaluating, and the knowledge needed for these processes, are described in Shulman's model of pedagogical reasoning (Shulman,1987). 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

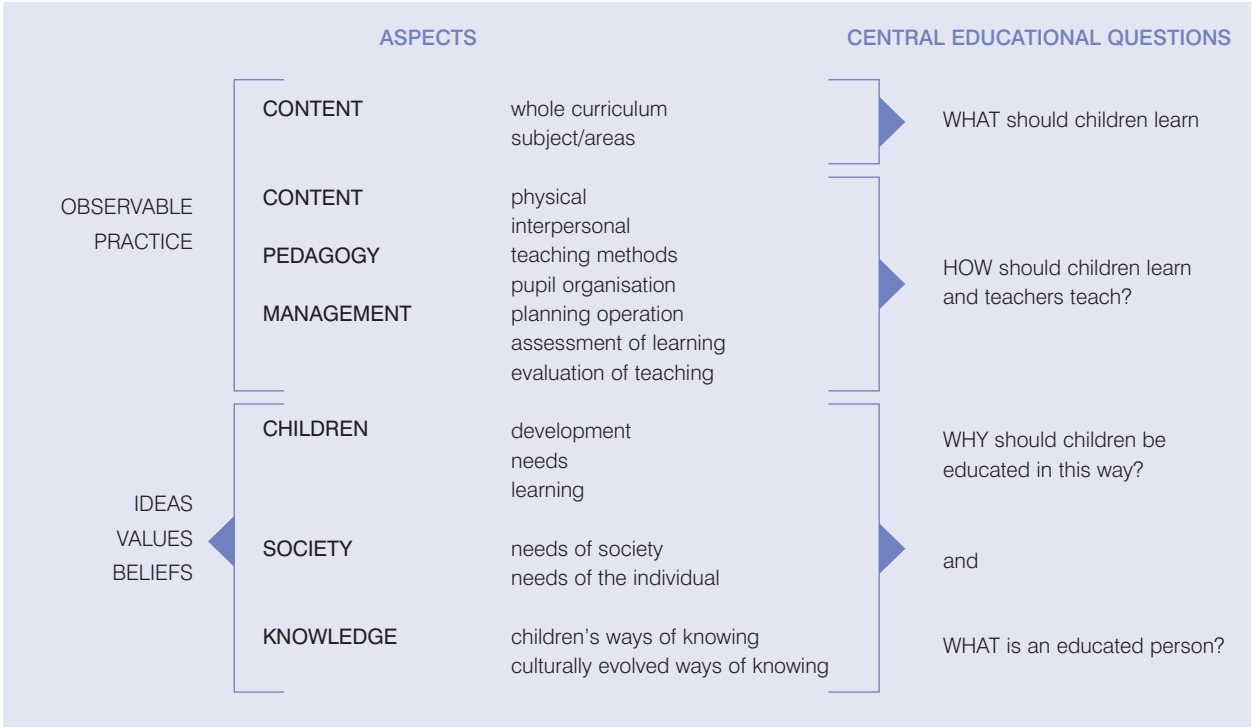


Figure 1.1 – Educational practice: A conceptual framework (Alexander, 1992, p. 184)

[1] Meta-cognition can be simply defined as 'thinking about thinking'. It refers to higher order thinking and includes activities such as planning how to approach a learning task and self-evaluation of progress in a task.

ICT and pedagogy

considered. According to Shulman, teachers' knowledge bases include the following categories of knowledge:

- Content knowledge.
- General pedagogical knowledge (knowledge related to general teaching issues, for example, teaching approaches and classroom management).
- Curriculum knowledge (knowledge about the 'tools of the trade': schemes of work, resources, and so on).
- 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 ends, purpose and values and their philosophical and historical grounds.

This list matches many of the elements in Alexander's list. One of the implications of this model for teachers' uses of ICT is that they need to have sufficient knowledge about the topic or subject. Therefore they also need to understand how this knowledge will be affected by the use of ICT, in order to make appropriate decisions about using ICT with 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 linked. In order to explore this link, Shulman's model of pedagogical reasoning (Shulman, 1987) focuses on the processes involved in teaching, including the transformation of knowledge and how this knowledge can be taught. An important component of knowledge in Shulman's model is pedagogical content knowledge.

The implication for the use of 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:

- Comprehension – examining the content to be taught and considering its interrelationships with other subject content.
- Transformation – transforming ideas of knowledge so that they can be learnt by pupils.
- 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, and so on.
- 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.

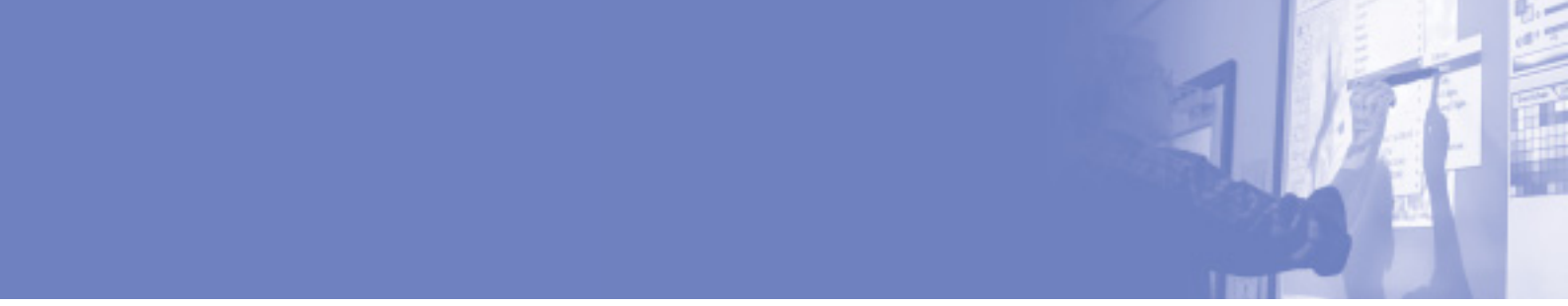
Learning environments, particularly those based on multimedia, are increasingly being described in terms of 'affordances'[2] which focus on how the learning environment is perceived by the user (Laurillard et al., 2000). Affordances may be similar to scaffolding,[3] but may be a more useful way of conceptualising aspects of the system, as scaffolding suggests something additional, possibly external to the system, whereas affordances may be integrated into the system.

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 pupils to build on their scientific ideas as they develop more and more powerful and useful pragmatic scientific principles.

[2] '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.

[3] 'Scaffolding' means that pupils build up knowledge and understanding by linking new concepts to those previous understood through a mental framework of linked concepts.



- Encourage pupils to investigate personally relevant problems and revisit their scientific ideas regularly.
- Scaffold science activities so pupils participate in the enquiry process.
- Model the scientific process of considering alternative explanations and diagnosing mistakes.
- Scaffold pupils' feedback to explain their ideas.
- Provide multiple visual representations from varied media.
- Encourage pupils to listen 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 pupils in reflecting on their scientific ideas and on their own progress in understanding science.
- Engage pupils as critics of diverse scientific information.
- Engage pupils 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 pupil drew on different pivotal cases to organise their thinking. For each class, the teacher needed to research pupils' understanding, analyse their thinking and identify pivotal cases that would build on pupils' ideas and inspire them to reflect on and restructure their views. The teachers then had to use these pivotal cases at appropriate times in discussion with the pupils. For example, a pupil 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 assessment procedures involve ICT, and there is much research evidence to show that the everyday practice of assessment in classrooms is beset with problems and shortcomings (for example Black and Wiliam, 1998). It is also especially difficult to measure 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.

Teacher-centred or pupil-centered 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 pupils' thinking processes or provide a basis for analysing pupil–teacher interactions, it may fail to address the important experiences resulting from ICT use. Understanding or identifying the thinking processes of learners, as far as possible, is particularly important for new technologies, since research has shown that new ways of learning and new representations are presented 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.)

However, there are aspects of pedagogy in the classroom, other than pupil-led ICT activities, which teachers need to embrace in order to devise and follow through worthwhile learning experiences with the use of ICT.

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 pedagogical roles for teachers in a technology-supported classroom as 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 to act as a catalyst in transforming the teaching and learning process (Hawkridge, 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 ICT was derived from the Palm project (Somekh and Davies, 1991). The authors identified pedagogical change as the following types of progress:

- '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.'

(ibid., p. 156–157.)

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

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 (2000) report to the then Department for Education and Employment has been particularly influential in the UK. The literature on effective teaching, including the Hay McBer report, makes little reference to the use of ICT.

The Hay McBer report looked for characteristics of teachers that were associated with good progress in pupils. They found that pupils' progress 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 include the complex analytical thinking required for planning and evaluating,

and the 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.*'
>
> (Shulman, 1987, p. 14.)

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:

> '*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.*'
>
> (Hay McBer, 2000. 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 *et al.*(1999), in a study of primary school teachers known to be achieving either average or above average gains on measures of relative attainment by pupils, focused on pedagogy using ICT. They 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 these 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.

Studies of teachers' views of pedagogy

The review by Watkins and Mortimore (1999) of research into practitioners' views on pedagogy suggested that teachers recognised the complexity of pedagogy and the complex nature of classroom life. Watkins and Mortimore 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 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.

Survey methods for measuring pedagogical knowledge are being developed. However, the multifaceted nature of the knowledge and the fact that much still needs to be learnt about its nature makes this a difficult task (Rowan *et al.*, 2001).

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' perceptions of these difficulties. They devised a diagnostic assessment instrument to elicit pupils' misconceptions of graphing, and used it as a questionnaire for teachers.

Many of these studies are considered in more detail in subsequent sections of this report.

Section 2 ICT pedagogy and attainment in subject areas

Overview of the research literature

The focus of this section is on the relationship between attainment and pedagogical practices involving the use of ICT, as revealed through published, empirical research. The studies that have contributed to this review can be classified into six main groups:

- **Bibliographies, literature reviews and meta-analyses**
  Several articles in this category made some analysis of pedagogy, although these did not focus specifically on pedagogy for ICT use at school. For example, Draper (1998) reviewed evaluations of software in use in higher education that was associated not just with satisfactory learning but with demonstrable improvements. A review by Scanlon *et al*. (2002) that aimed to develop understanding of technology-mediated practical work in science for higher education drew on studies at secondary school level.

- **Studies of effective teaching and teachers' views that make little reference to ICT use**
  One example is 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 is evaluated**
  An example of this type of study is Lavonen et al. (2003). Many of these studies focus 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 benefits of ICT and how it enables learning objectives to be achieved.

- **Studies associated with the introduction of an additional general ICT resource**
  Such resources include the use of laptop computers or 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 on the quality of 10- to 11-year-old pupils' investigative skills in science in six rural primary schools. They found no real indications that the use of email enhanced learning in science. In this instance, 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**
  See for example Moseley *et al.* (1999).

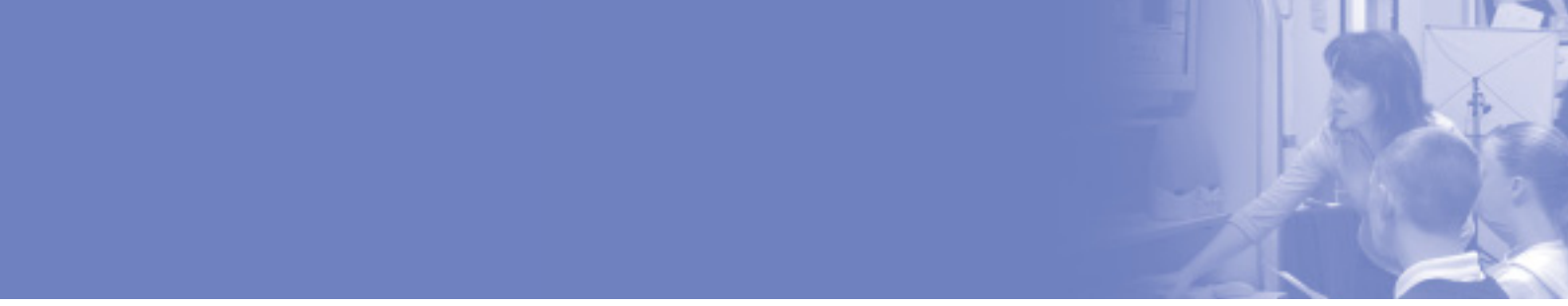
- **Longitudinal studies involving development work, usually over at least five years**
  These studies address the changing nature of teaching and learning associated with the introduction of technology. See for example Linn and Hsi (2000).

ICT in primary education – key aspects

There is evidence that ICT helps primary school teachers to be more effective in their teaching, especially if they are well resourced (Becta, 2001). In this series of reports analysing pupils' attainment at Key Stage 2 alongside Ofsted inspection judgements, statistically significant links have been revealed between the good use of ICT resources and higher attainment in ICT and other subjects. Given the nature of the analysis, this does not prove a causal link – that is, that the good use of ICT causes higher attainment – but it does point to an important and developing relationship. However, the reports also show that other factors, such as good leadership and the general quality of teaching, remain important.

Teachers' confidence with ICT has increased in recent years, but the use of ICT remains relatively low. According to government statistics (Department for Education and Skills, 2001), 75% of teachers reported that they felt confident in using ICT, 78% had received some training, and 71% had updated their training in the last two years. Yet a survey conducted by Preston *et al*. (2000) of 100 ICT teachers found that over 90% used only word processing more frequently than once a month out of all the generic applications.

Findings of a research and development project which investigated effective pedagogy with ICT in literacy and



numeracy in primary schools (Moseley *et al.*, 1999) provide illustrations of teachers' practices and the complexity of choices which teachers make in deciding when and how to use ICT to strengthen their teaching. At this time, many primary 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 to 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 to 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.

This study also recognised the value of support from the head teacher, or of a collaborative working environment. It suggested 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. As new equipment and software become available, teachers will need to develop new skills and pedagogical approaches.

A literature review for the evaluation of Digital Opportunities projects in New Zealand (Boyd, 2002), in analysing the lack of impact of some innovations involving laptops, includes this valuable reminder that it is the type of use that is most important:

> '*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.*'
>
> (Boyd, 2002, p. 30.)

It is also important to consider the extent of home use of ICT, and the way this may affect pupils' perceptions of school use. Research suggests that there is a gap between the types of use at home and at school. One survey (Mumtaz, 2001) of pupils in years 3 and 5 (ages 7–8 and 9–10) found that the most frequent activity at school was word processing (which the pupils found boring), while the most popular activity at home was playing games. As a result, the author suggested that schools should learn from what works at home and allow pupils to work on activities that they find valuable, motivating and worthwhile. Another problem arises from the fact that pupils' computers at home are often far in advance of those they have access to at school. Teachers need to acknowledge pupils' innovative uses of technology at home when developing their practices at school (Comber *et al.*, 2002).

This said, while many primary school children could be considered to be sophisticated and knowledgeable users of ICT, access to ICT resources at home does vary widely. The study by Selwyn and Bullon (2000) of 267 year 2 and year 5 children in south Wales revealed 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 and drawing were identified as the most widely experienced uses of computers. Given that home use is variable, the authors argued that the paramount role of schools should be to balance the needs of the computer 'haves' and 'have lesses'.

Organisation

In a study of three primary schools, Goodison (2002) confirmed that a range of organisational factors, such as the commitment of the head teacher and good forward planning, were correlated with successful implementation of the use of ICT, and the commitment of staff played a pivotal role in the process. However, as Goodison pointed out, the implementation of new technology needs to be managed properly, to ensure the continued commitment of teachers.

Group work

There is little evidence in the research literature to indicate that collaboration inevitably enhances learning.

ICT and pedagogy

As Eraut (1995) has pointed out, group work is a complex process which limits the ability to generalise on its benefits, but his study involving 19 case studies in 16 classes of 8- to 12-year-olds offers strong support for a Vygotskian[4] rather than a cognitive conflict[5] explanation of the benefits of group work among pupils.

Yu (2001) examined the effect of competition in computer-assisted co-operative learning situations on pupils' cognitive, affective and social outcomes, in a study of 192 5th-grade students (aged 11–12 years) in six classes in one Taiwanese school. The results showed that co-operation without competition engendered better attitudes towards the subject matter and promoted more interpersonal relationships. However, studies of pupils using ICT at primary school level suggest that effective pupil collaboration for learning is not easily achieved (Crook, 1998)

ICT in secondary education – key aspects

Two of the fundamental differences between primary and secondary schools are in the allocation of ICT resources and the cross-curricular nature of primary education compared with the subject-specific teaching and organisation in secondary schools. Most primary schools have a few computers in each classroom, and sometimes an electronic whiteboard, whereas most secondary schools have a greater emphasis on networked computer rooms. In some secondary schools, ICT is taught as a discrete subject within an ICT department; in others ICT is taught across the secondary curriculum through other subjects (Beauchamp, 2003). The 2001 survey by the British Educational Suppliers Association (BESA, 2001) found that in 86% of secondary schools the majority of computers are located in labs, compared with only 16 per cent for classrooms, while in primary schools the equivalent figures are virtually equal.

This difference has implications for teachers' pedagogies, for example it has been shown to be a key influence on the way primary school teachers have been using ICT (Watson, 1993, Selwyn and Bullon, 2000). In secondary schools, there is more focus on ICT within subjects, but the demands of ICT teachers who are responsible for teaching ICT as a subject can limit other teachers' access to the technology (Beauchamp, 2003).

The following sections discuss the research evidence relating to pedagogy and attainment with ICT in specific-subject areas. Further research relating to attainment can be found in the companion literature review to this publication (Cox and Abbott, 2004).

English

Primary English

The first ImpacT project (Watson, 1993) found teachers using a range of software, including word processing, in primary school English lessons. However, there was a conflict between teachers wanting to help pupils progress in their writing by the use of word processing, for example, and their desire to ensure that all pupils had equal access to the computer. This resulted in each pupil in some classes only having about five minutes' use of word processing per term. Because there was only one computer in the classroom and the teacher wanted to provide equal access for pupils, this led the teacher into 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 evidence from the ImpaCT2 project case studies (Comber *et al.*, 2002). The results again suggested that because of the limited number of computers in primary classrooms, the sustained and regular use of ICT rarely occurred. For ICT to have any benefit, teachers therefore need to make the right decisions to enable pupils to have frequent and substantial access to resources.

Mumtaz and Hammond (2002) found that much of the use of word processing at primary level is individualised and largely for presentational purposes – that is, mainly for entering texts previously written by hand. These researchers reported little intervention by teachers in this activity. They conclude 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.' (ibid., p.346.)

The preliminary results of a survey designed to identify how talking book software[6] was being used in the classroom (Lewin, 1998) highlighted the success of this type of

[4] Vygotsky's 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.

[5] 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.

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 to provide additional reinforcement activities which would enable the software to meet the needs of individual learners more effectively. The results showed that the software was used mainly with pairs of children (82%), but occasionally with individuals (29%). A smaller number of teachers specified that the software was usually used by groups of three or more children at one computer (11%). 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 which 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.

Secondary English

Much of the empirical evidence in English reports similar uses of ICT to those 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' experiences of writing a series of hypertext[7] stories over an 18-month period. Each individual story was 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.

Mathematics

There is much reported research into the uses of ICT in mathematics teaching at both primary and secondary levels. Some large-scale studies involve investigating the effects of a range of ICT environments, and others focus on specific uses of ICT. 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.

Primary mathematics

The research evidence shows that, in order to integrate ICT into their mathematics teaching, it is necessary for teachers to have a substantial understanding of ICT resources and familiarity with a range of applications. Effective uses of ICT should enable pupils to focus on reasoning rather than on answers, and enable them to develop significant mathematical strategies and connect mathematical ideas with the real world.

[6] Talking books are designed to be read on a computer, with a combination of features such as text, photographs, drawings, animations, sound effects and video, and often the option of having the computer read out the text for the user. They are usually stored on CD-ROM.

[7] Hypertext documents are usually presented by a computer, and contain a web of links to separate but related texts. They express the non-linear structure of ideas.

ICT and pedagogy

When teachers use ICT in ways which challenge pupils' thinking and engage them in investigations, pupils demonstrate a higher order of mathematical reasoning and increased attention than when teachers adopt a 'transmission' view of teaching (where knowledge is 'transmitted' directly from teacher to pupil). For example, Connell (1998) concludes that technology should be used as a tool for pupils to create 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 such pupil representations. For more details of this study see the section on mathematics in secondary teaching (p.17).

Large-scale projects

Topics within the first ImpacT study (Cox, 1993) included the use of ICT and mathematics in primary schools. The results did show a positive effect for the use of ICT in mathematics in the 8–10 age range (see also Johnson *et al.*, 1994). The conclusions on pedagogy 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.)

Another large study involving over 2,000 middle school pupils (Waxman and Huang, 1996) examined whether the degree of implementation of technology in mathematics classes affected outcomes such as changes in classroom organisation and interaction, the selection of activities, and pupils' on- and off-task behaviour. The results indicated that there were significant differences in instruction in the classroom depending on the amount of technology used. Whole-class approaches, where pupils generally listened to or watched the teacher, tended to be used in classrooms where technology was not often used, whereas in classrooms where technology was used moderately there tended to be much less whole-class instruction and more independent work. This study suggests that the use of technology may help to change teaching from a traditional teacher-centred approach to one that is more pupil centred. In addition, pupils in classrooms where technology was used moderately were found to be significantly more 'on task' than pupils in classrooms with less use.

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 the use of ICT produces some improvement in pupils' performance for a limited set of tasks. As the review by Hennessy and Dunham (2002) points out, studies involving contrasting control and experimental groups are fraught with difficulties because complex factors arising (particularly teachers' behaviours and pedagogy) are rarely accounted for; fair comparisons using test scores alone are almost impossible. Further, ICT itself can play an important role in shaping the mathematical activity being studied.

In a meta-analysis[8] 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 pupils' collaboration resulted in 'deep conception', and the pupils seeing 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. However, such results could 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).

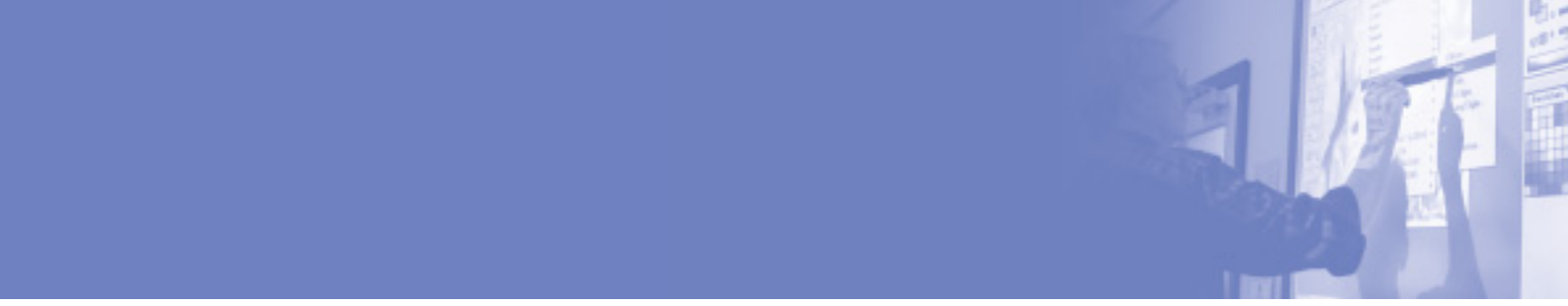
Another convincing experiment, but with a very small sample (McFarlane *et al.*, 1995), introduced line graphs to 8-year-old children, using data logging. Children who had been exposed to data logging showed an increased ability to read, interpret and sketch line graphs when compared to children using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

Programming and microworlds

One of the most widely researched areas of ICT in mathematics is programming and using microworlds.[9] Many studies using the programming language Logo with primary school children have been reported. The use of Logo has been shown to improve children's estimation of distance (Campbell *et al.*, 1991) and improve their

[8] A meta-analysis is a study which aggregates the findings from many other studies.

[9] 'Microworld' is a term coined at the MIT Media Lab Learning and Common Sense Group. It means a tiny world inside which a pupil can explore alternatives, test hypotheses, and discover facts. It differs from a simulation in that the student is encouraged to think about it as a 'real' world.



ability to create accurate sets of instructions to plot a path through a maze (Johnson and Kane, 1992).

In a meta-analysis, Clements (2000) described a number of ways in which the appropriate use of Logo programming has been shown to help pupils. These include the development of higher levels of mathematical and especially geometric thinking, and problem-solving skills (Au and Leung, 1991), and enhanced social interaction (Yelland, 2003).

In a study of primary school pupils using Logo, Cope and Walsh (1990) found that pupils who spent a long time programming became more accustomed to sustained intellectual activity, which had positive benefits for their work in other areas of the curriculum. However, some problems may arise if too little time is spent ensuring that pupils have sufficient prior mathematical knowledge (Cope *et al.*, 1992).

There is some debate regarding Logo as to how much learning by autonomous discovery should be expected of pupils (Hoyles and Noss, 1992). 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 between Logo environments and school mathematics.

Results from one study pointed out that Logo may foster cognitive growth, in part by engendering effective motivation, because 'success' is determined internally within the Logo environment (Nastasi and Clements, 1994), though pupils may still seek external approval. 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 (encouraging pupils to co-operate), since such concepts cannot be taught directly (Sutherland, 1993). Other findings have supported the efficacy of Logo as a medium conducive to the teaching and learning of problem solving, but only when particular problem-solving skills are taught explicitly (Swan, 1991).

These technologies have also been shown to support collaborative learning. Xin (1999) examined the effects of computer-assisted co-operative learning in the USA 3rd-grade 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) of 28 year 2 children who worked in pairs on tasks in a microworld embedded in a mathematics topic reported that the children engaged in activities with a high level of concentration and found them both challenging and fun to complete.

Internet use

There is little research into the effects of internet use on teachers pedagogies and pupils' attainment in mathematics at primary level, although there are early suggestions that websites dedicated to mathematics could encourage more effective teaching (Jones and Simons, 1999). More data specific to the pedagogy of teaching primary mathematics when using such websites is needed. New research should examine both the pupils' and teachers' use of such a resource for both teaching and learning, and its effectiveness in positively affecting learning outcomes.

Secondary mathematics

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

Moseley *et al.* (1999) identified that a key feature of more effective teachers was their use of 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 match pedagogy with the intended learning outcomes of an activity. However, Brown *et al.* (2001) failed to identify any factors relating to pedagogical practices which might have significant effects on pupils' attainment. Although this research cast doubt on claims that teachers' effectiveness can be rigorously assessed by observation in the classroom, the study team did identify many behaviours that they felt most reliably distinguished effective teachers. These included challenging pupils to think mathematically, ensuring a consistency between task and objectives, using a range of modes of expression, and focusing on reasoning rather than answers.

ICT and pedagogy

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 (where pupils' learning is based on them reconstructing and adding to their existing knowledge), but the use of ICT did help to develop pedagogy: '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.)

Similarly, Goos *et al.* (2003) in a three-year project in Australia found that teachers' 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 particular, it was found to be the way in which the teacher orchestrates pupils' interaction with the task, the technology and their peers which was crucial to pupils' success (in this case in finding a solution to a cubic equation). The researchers suggest four roles for technology in relation to such teaching and learning interactions: 'master', 'servant', 'partner', and 'extension of self'. Their report highlights the vital role of the teacher in moving pupils towards more thoughtful and powerful ways of working with technology.

The vital role of the teacher is echoed by Glover and Miller (2001), in a smaller study exploring the impact on teaching of the use of interactive whiteboards in one comprehensive secondary school. Such technology is likely to have limited impact where teachers fail to appreciate that interactivity requires a new approach to pedagogy.

Hennessy (2000), working with graphing software on palmtop computers, observed that the main gains were in the motivation of the pupils. Graph plotting became simple, giving the teacher more time for other, more interesting learning activities. However, the teachers did not find any greater benefit from using the spreadsheet software on the palmtops compared with using it on the desktops already available to them.

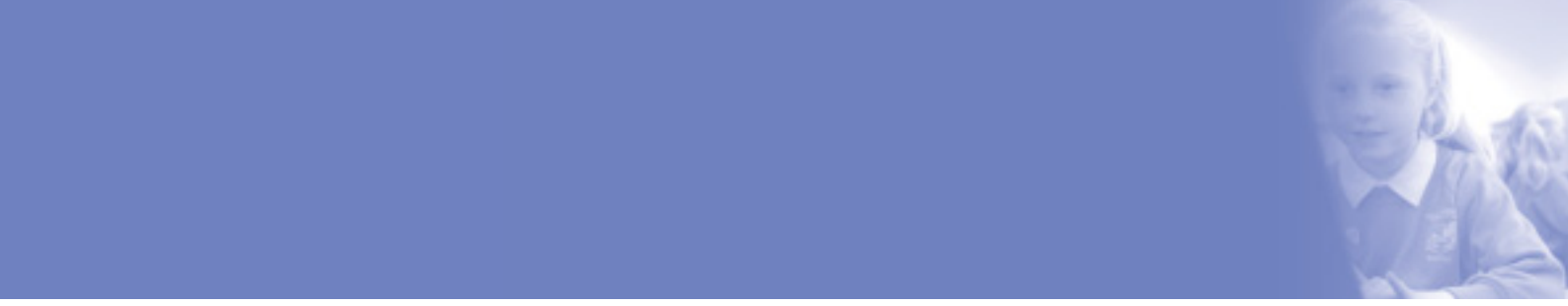
Connell (1998) investigated the potential roles which technology might play in enhancing a constructivist approach. He observed two classes from the same school in a rural area over a one-year period. Both classes were taught by teachers who agreed to implement technology within their lessons in markedly different fashions. One class adopted a constructivist approach and utilised the computer as a tool for pupils for mathematics exploration, the other as a presentation tool, more in line with a behaviourist[10] approach. By the end of the research period, both classes had shown a significant improvement in achievement, and easily surpassed both regional and local achievement goals. The pupils in the class where the use of technology was consciously aligned with the guiding constructivist philosophy showed a marked and consistent increase in performance.

In a summary of research on dynamic geometry systems,[11] 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 that 'the teacher plays a very important role in guiding students to theoretical thinking.' (ibid., p. 20.)

The use of computers to support constructivist pedagogy was shown to be effective by Dreyfus and Halevi (1991) also. They showed that the use of computer programs to provide an open learning environment allowed pupils to explore within a framework, and, given that the teacher was working as a guide, even weak students were able to deal in depth with a difficult topic. Alternatively, Hoyles and Noss (1992), as a result of their studies in Logo-based microworlds, suggested that teachers restrict the software environment within which pupils may explore and within which pupil autonomy and mathematical expression may take place.

[10] The behaviourist approach studies observed behavioural responses of humans and animals. The approach is based on the belief that we learn to behave in response to our environment, either by stimulus–response association, or as a result of reinforcement.

[11] Dynamic geometry systems are software packages which allow users to create shapes and mathematical models and then explore their properties.



Science

The most extensive uses of ICT in education have been in science at both primary and secondary levels. This can be seen through different types of ICT environments such as simulations and modelling, as discussed below.

Primary science

Simulations

For practical reasons, it is not possible to study certain scientific processes first hand in the primary classroom. ICT provides opportunities for pupils to explore simulations of these processes in the classroom, where previously they would have needed to travel to a science centre or museum. A body of researchers have investigated the extent to which ICT-based simulations can substitute for advanced experiments or experiences in a museum or science centre.

For example, Baxter and Preece (2000) found that the learning of 48 pupils in years 5 and 6 (9- and 10-year-olds) when they were taught with the aid of computer planetaria was equally effective as teaching with dome planetaria. Pupils worked in pairs at a computer, using planetarium software.

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, 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 when pupils are building scientific models. This study and others have shown 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 which they were trying to achieve.

Jarvis *et al.* (1997), for instance, evaluated the effect of collaboration by email on the quality of 10- to 11-year-old pupils' investigative skills in science in six rural primary schools. Although the children demonstrated a variety of scientific skills, in particular observing and recording, and developed some general computer skills, there was no indication that the use of email enhanced their learning in science. The influence of the teacher was recognised as a crucial element. When 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.

Secondary science

Simulations

The evidence from experimental studies shows that various aspects of achievement can be improved by integrating simulations into topics that pupils find conceptually difficult. The activities set by the teacher involving simulations are often problem solving and enquiry tasks, in which pupils interact with each other as well as with the teacher. Although these studies rarely consider pedagogy in detail, they do suggest that the collaboration between pupils was an outcome that was encouraged, but not specifically designed, by the teachers, and that the collaboration is one of the factors that leads to improved attainment.

Computer simulations of experiments are often used in short episodes in existing curricula. For example, Huppert *et al*. (1998) conducted an experimental study of the effect of using computer simulations on 10th-grade pupils' (year 11 in the UK) ability to apply their knowledge to the growth curve of micro-organisms. The use of simulations allowed the pupils to carry out investigations more quickly and focus on analysing the results and hypothesising. The structure of the course helped to create a collaborative learning atmosphere, with pupils comparing results and exchanging ideas. These aspects resulted in gains in cognitive learning.

Tao and Gunstone (1999) investigated the use of computer simulations integrated into 10 weeks of physics instruction for one class in an Australian high school. The simulations were specifically developed to confront pupils' alternative conceptions in mechanics. The classroom study investigated whether and how collaborative learning using computers fosters conceptual change. The programs provided the pupils with many opportunities for the co-construction of knowledge. During the process, pupils complemented and built on each other's ideas and incrementally reached shared understandings. Their interactions led to conceptual change. Although this study did not directly address the role of the teacher, it does suggest the desirability of providing opportunities for collaborative learning.

Another type of subject-specific software that has been used frequently in studies is software 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, an aspect which is often neglected in teaching. Draper (1998) refers to work by Tasker, who has developed extensive animations accurately simulating these properties of molecules. This is described as a rare example of a deep pedagogical motivation for using simulation and animation, and pilot trials suggested that this approach is very powerful in stimulating learners to make new and important connections between fragments of their existing knowledge.

Dori and Barak (2001) used a combination of physical and virtual modelling to support the development of conceptual understanding. They conducted an experimental study with 276 pupils from nine high schools in Haifa and the northern part of Israel using a new teaching method that combined physical and virtual three-dimensional molecular models. The pupils in the experimental group gained a better understanding of the concepts illustrated by the model and were more capable of defining and implementing new concepts. They were more capable of mentally traversing across four levels of understanding in chemistry: symbol, macroscopic, microscopic and process. Students in the experimental group 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 of applying reverse transformations. The researchers found that the enquiry-based learning tasks encouraged understanding of organic compounds and provided pupils with tools for explaining their answers.

Howe and Tolmie (1998) describe the use of the specially developed software to help collaborating pupils test hypotheses (relating to water pressure and shadows), an activity thought to be relevant to conceptual learning. The software was used by 9- to 14-year-old pupils, and their activity compared with that of similarly aged pupils who worked with otherwise equivalent software, but which lacked prompts regarding the extent to which inputs from pupils were inappropriate. The findings support the value of the prompting, which has implications not only 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.

Producing multimedia and video

Michel *et al.* (1999) suggest that allowing pupils to make video clips can develop their powers of observation and open new perspectives for their understanding of scientific concepts. This is because pupils need to think about exactly what should be recorded in order to explain a concept. This type of enquiry-based teaching involves pupils in deciding which problems to investigate, searching for alternative solutions, collecting and tabulating data, reporting conclusions, and suggesting new related problems for further investigation. The technology also gives teachers the flexibility to demonstrate scientific concepts through a method other than a live demonstration. In one example from this study, a high school biology teacher produced a CD-ROM of short clips digitised from tapes made by pupils during a long-term experiment to grow various plants. The pupils later incorporated the clips into scientific presentations.

Reid *et al.* (2002), in an evaluation of a pilot study of digital video in 50 schools in the UK, reported that teachers found that filming and editing a video about forces helped pupils to assimilate scientific concepts more effectively, quickly and substantially than would have been achieved with handouts or textbooks.

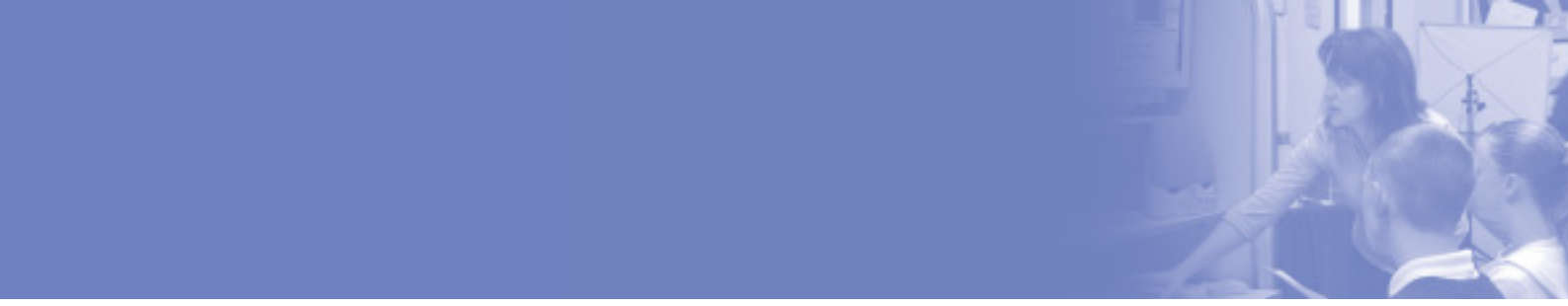
Real-time graphing

Barton (1997), in a review of research on data logging, concluded that the main benefit is the time saving, but suggests that the important factors of interaction with peers and intervention by the teacher need further research.

Linn and Hsi (2000) found that pupils are much better at interpreting the findings of their experiments when they use real-time data collection than when they use conventional techniques for graphing their data, and that this greater understanding is carried over to topics where they have not collected the data.

Distance education

McKinnon and Nolan (2000) describe a distinction course on cosmology for secondary-aged gifted and talented pupils in which a 'learning community' supported by ICT largely replaced the traditional role of the teacher. Instead, the course co-ordinator and astronomers acted as learning facilitators, mentors and discussion partners. This allowed pupils to manage their own learning, with the necessary



support, and to achieve results that were personally satisfying. Achievements in this context are very much individual, but this course did result in pupils achieving work of a very high standard.

A teacher-based case study (Poland *et al.*, 2003) involving the use of a 'virtual field station' for the teaching of an A-level biology topic (about Mediterranean sea turtles) showed that this was an effective substitute for a real field study, in terms of the development of pupils' knowledge and their understanding for examination purposes.

Long-term small-scale innovations

Long-term small-scale studies provide much better opportunities for examining the complex issues of the role of the teacher and interactions in the classroom, both between pupils and between teachers and pupils. For example, the Computer as Learning Partner (CLP) collaboration at the University of California (Linn and Hsi, 2000) was a longitudinal study involving the development of a curriculum and associated pedagogy for a semester-long science course that aimed to integrate the appropriate use of ICT. It is one of the few studies where the use of ICT was planned into a new curriculum and the process and outcomes were researched. The project encouraged pupils to explore many different ideas about any given science topic, while helping them combine and restructure these ideas so they formed a coherent and comprehensive perspective on the problem. The design of the CLP curriculum focused on guiding the process of connecting, linking and reorganising, so that pupils could concentrate on thinking about their experiences in productive ways. Following a whole-class discussion, pupils engaged in real-time data collection or simulated investigations, then were asked to share results and come to some consensus on principles and their relationship to real-life experiences. Adding simulations to the curriculum helped pupils to integrate their understanding and apply their ideas to a broader range of problems. The software used in the study freed the teacher from answering basic organisational questions and provided time for the teacher to probe pupils' understanding. It also provided scaffolding for pupils to write their own principles based on their experimental results, and included a range of different types of visualisation of various processes.

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 technology employed in the project (simulations, multimedia, microcomputer-based laboratories) was intended to enhance the instruction done by the teacher, rather than replace it, so tutorial-type applications were excluded. Typically, several different activities were in progress simultaneously. Pupils could choose to work individually, in pairs or in small groups. The researchers reported that the pupils had a strong sense of purpose and immediate engagement with lessons.

Other research has also reported increased engagement. Smith (2002) describes how the use of linked web pages to construct identification keys with year 8 pupils (ages 12–13) made the topic of taxonomy interesting, whereas it is often seen as boring and outdated. The web-based nature of the keys enabled them to be exchanged via a network. Pupils developed transferable ICT skills as well as observation skills and an understanding of classification and biodiversity.

Humanities

Primary humanities

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

Secondary humanities

Hennessy *et al.* (2003) investigated teachers' and pupils' changing roles and strategies when using various forms of computer-based ICT in secondary school English, history, geography, science, technology and classics lessons. One hundred and fifteen 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 the six curriculum areas. The use of ICT was associated with a decrease in direction by, and exposition from, the teacher, and a corresponding increase in self-regulation and 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 and guide learning, structure activities more carefully and maintain a focus on the subject, monitor progress, and encourage reflection and analysis.

Copeland (1991) suggests that the use of computers might be beneficial to the success of historical enquiry

teaching. Seven teachers, teaching 20 classes of secondary school students, were involved in the study. Software enabled teachers to teach in a way they would not otherwise, but this did depend on the teachers carrying out sufficient preparation.

The use of multimedia learning environments in secondary school geography teaching has been shown to bolster interactions in the classroom (Smeets and Mooij, 1999). Pupils were randomly allocated to an experimental group using multimedia learning environments, and a control group using traditional methods. Although no differences were found in gains, the results showed a significant increase in interactions between the teacher and pupils and between pupils during lessons involving the multimedia learning environment compared to traditional lessons.

Beishuizen (1992) in a study of two secondary school classes of 20 and 18 pupils showed that simulations can aid the retention of facts and concepts. Simulations were used in geography teaching to model the relationships between erosion and agriculture in a developing country. The researcher suggests that for this study the pupils were not ready to explore the simulation environment in a systematic way, and that more training was needed for both the teacher and pupils for them to take full advantage of the simulation environment.

Research conducted by the first ImpacT project (Watson, 1993) reaffirmed that outcomes where ICT is used in geography depend on the teachers' aims and objectives and their skill in ensuring these are met. The use of simulations was, however, found to enable pupils to develop a high degree of empathy with the topic under study.

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

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

ICT

Primary ICT

A review of the literature reveals that there is little research into either pedagogy for ICT as a subject or into the process through which skills and understanding in ICT develop in children (Webb, 2002). Wood (2001) argues that greater knowledge and understanding of ICT processes are required in addition to skills if pupils are to make effective use of ICT, but many teachers appear to assume that no input is required from teachers during lessons, and that pupils will learn from the computer or from each other.

Webb (2003) suggests that two key elements of the content understanding required for ICT-based problem solving (a key aspect of ICT) are: the concepts and techniques of representing data, knowledge and processes; and the capabilities of types of software application. These may be best addressed by pedagogies based 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 and science, where children are expected to develop their understanding of concepts as well as their numeracy and ability to conduct experiments, so in ICT children need to develop their understanding of ICT systems and processes as well as the skills to use ICT.

Studies of existing practice suggest, however, that much developmental work is still to be done. 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 that although the majority of children were making some use of computers in school, few children engaged in sustained periods of ICT use or used many different applications.

Mumtaz and Hammond (2002) observed nine teachers giving lessons to Key Stage 2 children in five primary schools and found that work with word processors was largely individualised and for presentational purposes (mainly entering texts previously written by hand), and that there was little intervention by teachers.

Secondary ICT

Cope and Walsh (1990) conducted a review of research on the teaching of programming, and noted that the development of programming skills requires a much larger time commitment than is often allocated. Computer-based modelling has been found to offer great potential for the development of causal, spatial and common-sense reasoning (Mellar *et al.*, 1994). These researchers investigated the uses of both qualitative and quantitative modelling with secondary school pupils using different modelling environments. 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.

ICT in other subjects

There are research studies reported in the literature about the effects of ICT on the teaching of art, physical education 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 physical education.

Section 3 Emerging themes

From the theories and the literature review discussed in the previous sections it is possible to identify a number of emerging themes relating to teachers' pedagogies and the use of ICT.

Collaborative learning

The previous section discussed many research studies which point to the role of ICT in supporting collaborative learning. Crook (1998), in his review of research on collaborative learning in primary schools, concluded that there is evidence from experimental studies that peer-based learning improves performance, but that effective collaboration between pupils is rare. According to Crook, successful collaboration requires explicit orchestration.

Studies of pupils using ICT also suggest that effective collaboration for learning is not easily achieved between pupils. For example, a case study was conducted by Kumpalainen and Mutanenen (1998) of nine pairs of primary school pupils working collaboratively in a multimedia CD-ROM environment in science. The pupils did not, however, produce effective collaboration. Rather than supporting scientific learning, the pupils focused on activities relating to the use of ICT, such as organising working processes and producing neat poster presentations. The actual collaboration was minimal.

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

Collaboration between pupils has been a key element in classrooms involved in the Technology-Enhanced Secondary Science Instruction (TESSI) project, discussed in the previous section. Pedretti *et al.* (1998) report that pupils in these classrooms identified that such collaboration helped them to learn better, particularly by clarifying understandings and supporting deeper learning. Mayer-Smith *et al.* (2000) reported that teachers in the TESSI classroom facilitated learning by working with small groups of pupils, directing them to useful resources, and helping with problem-solving activities. Traditional lecture-based teaching diminished substantially and was replaced by shorter lessons. Direct instruction was limited to short introductions to new units, the revisiting of concepts that pupils found challenging, and end-of-unit summaries.

Howe and Tolmie (1998) report that when teachers are present, the flow of communication is mainly from teacher to student (in this case, in a university tutorial group) and vice versa rather than between students, thereby limiting collaborative learning. It may be difficult for teachers to support collaborative learning because it requires new behaviours, for example 'contingent support' which allows increasing degrees of freedom after signs of learning. Such contingent support is labour intensive for the teachers, and the researchers suggest that computers could play an important role here.

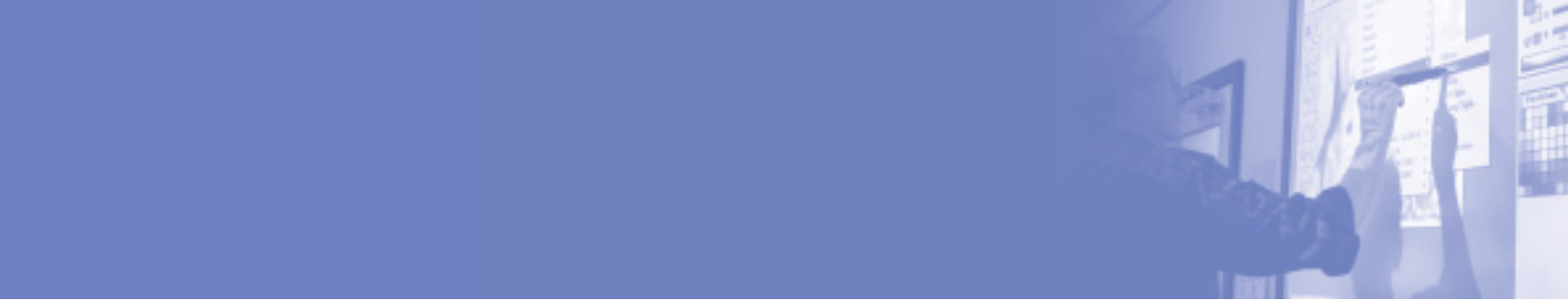
Lesson preparation

Few research studies include measurements of the planning and preparation which teachers have to conduct in order to use ICT confidently and effectively. Teachers themselves often do not report on the preparatory and supporting work which is part of their pedagogy. While ICT may enable and encourage teachers to play more of a facilitating role in the classroom, the available evidence also shows that the need to plan activities and assess pupils' learning outcomes means that the overall role of the teacher remains as a leader and subject expert.

Listening to pupils

When pupils are demonstrating their understanding using an electronic whiteboard, or working collaboratively in pairs at a computer, many teachers have reported that they can gain deeper insights into pupils' understanding than if they were interacting with the class as a whole.

For teachers to benefit from the contributions that ICT can make to pupils' learning in primary schools they need to have detailed knowledge of and expertise in ICT, the range of possible representations of knowledge, and the ways in which use of ICT might change their



pedagogies. From the evidence in the literature, this will require further substantial training for the majority of primary school teachers, both to use a range of ICT resources and to adopt new methods of teaching without discarding their existing best practices.

Control of the learning

As discussed earlier, Hennesey *et al.* (2003) found that the use of ICT was associated with a decrease in direction from and exposition by the teacher, a corresponding increase in pupil 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 and guide learning, maintain a focus on the subject, monitor progress, and encourage reflection and analysis.

A revealing quote from the TESSI project suggests that pupils also have to grapple with the implications of this different style of learning (Pedretti *et al.*, 1998, p. 582):

> *"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."*

The self-pacing aspect of the TESSI course required pupils 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 technology. However, a small minority of pupils reported that they preferred to learn in a more teacher-centered environment, with detailed directions and firm deadlines.

Further, one of the key benefits of these new technologies, the possibility of greater control of the learning process by the pupils, can become disadvantageous if it results in the absence of structure. Laurillard (1998) reported that learners working on interactive media with no clear narrative structure tend to be unfocused. Teachers need to prepare instructional worksheets or offer supervision in order for the activity to be productive.

Pedagogical framework

In this section, frameworks that have been used for analysing the use of ICT are briefly reviewed, and relevant features of these are combined with aspects of the pedagogical reasoning processes to suggest an emerging list of pedagogical practices relating to ICT use.

The first ImpacT study developed a 10-point scale for recording and analysing the uptake and use of ICT (Cox, 1993), but not for recording and analysing the quality of use. The development of a 'concerns-based adoption model' at the Research and Development Center for Teacher Education in Austin, Texas has produced an extensive 'levels of use' scale (Loucks *et al.* 1998). This scale uses various categories of quality of ICT use which have been used to record, rate and assess the extent of integration in teaching. This model includes seven factors: knowledge, acquiring information, sharing, assessing, planning, status reporting and performing. The model has been used in several studies to capture the uptake and use of ICT in teaching.

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 classification by Kemmis *et al.* (1977) of four paradigms for computer-assisted learning. These classifications help to define the roles of the computer and the pupil. More recently, Squires and McDougall (1994) have reviewed approaches to evaluating educational software, and have outlined the Perspectives Interactions Paradigm (see Figure 3.1), which focuses on evaluating the interactions between three key actors: pupil(s), teacher and designer (of the software). This framework provides a basis for categorising the locus of interactions, but does not address the nature of those interactions.

Laurillard *et al.* (2000) have developed a 'conversational framework' (see Figure 3.2) from research on 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 the learning process. These interactions might involve a short dialogue with the teacher explaining something, suggesting a practical example, and commenting on the pupil's performance, or a much more attenuated period covering several encounters, class sessions, assignments and debriefing.

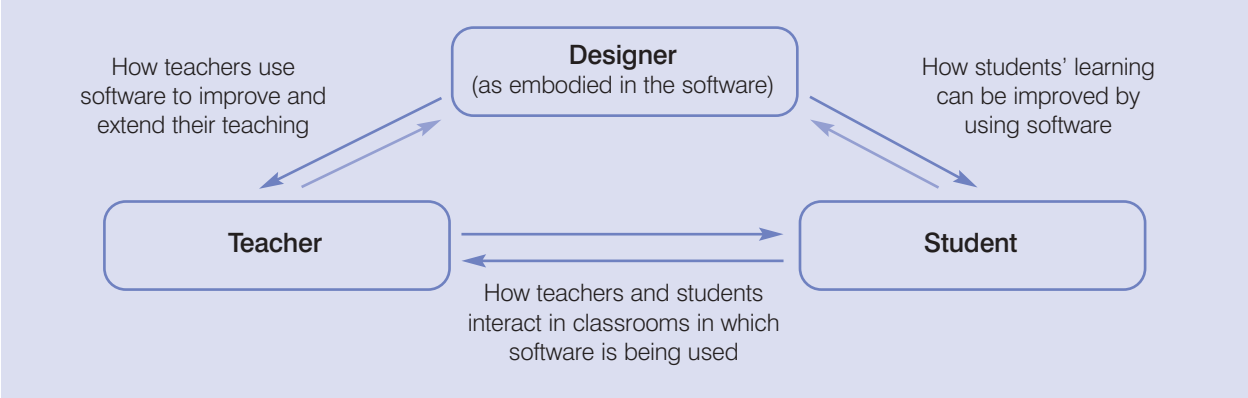


Figure 3.1 – The Perspectives Interactions Paradigm

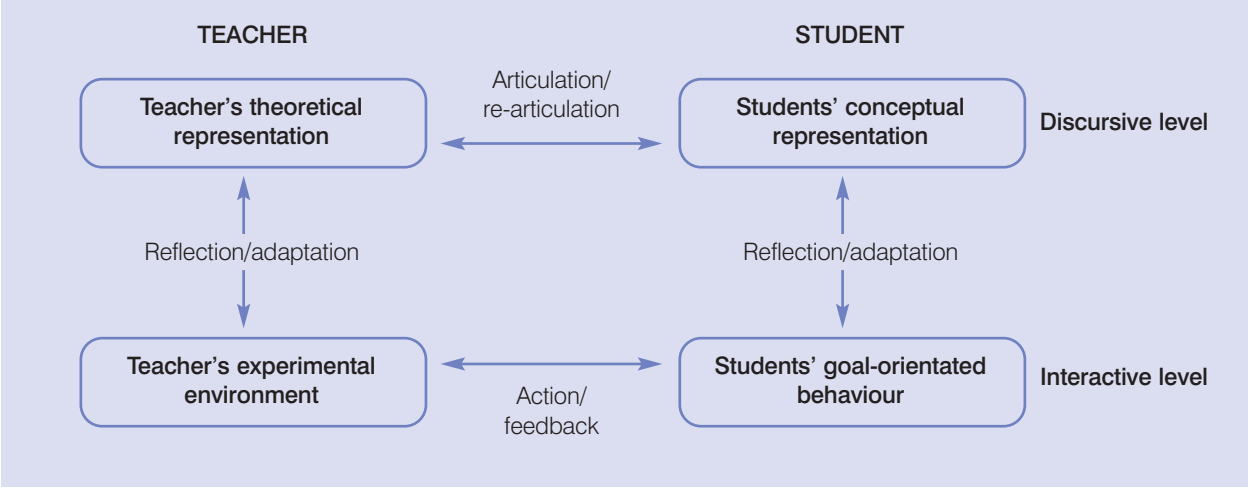


Figure 3.2 – Laurillard's conversational framework

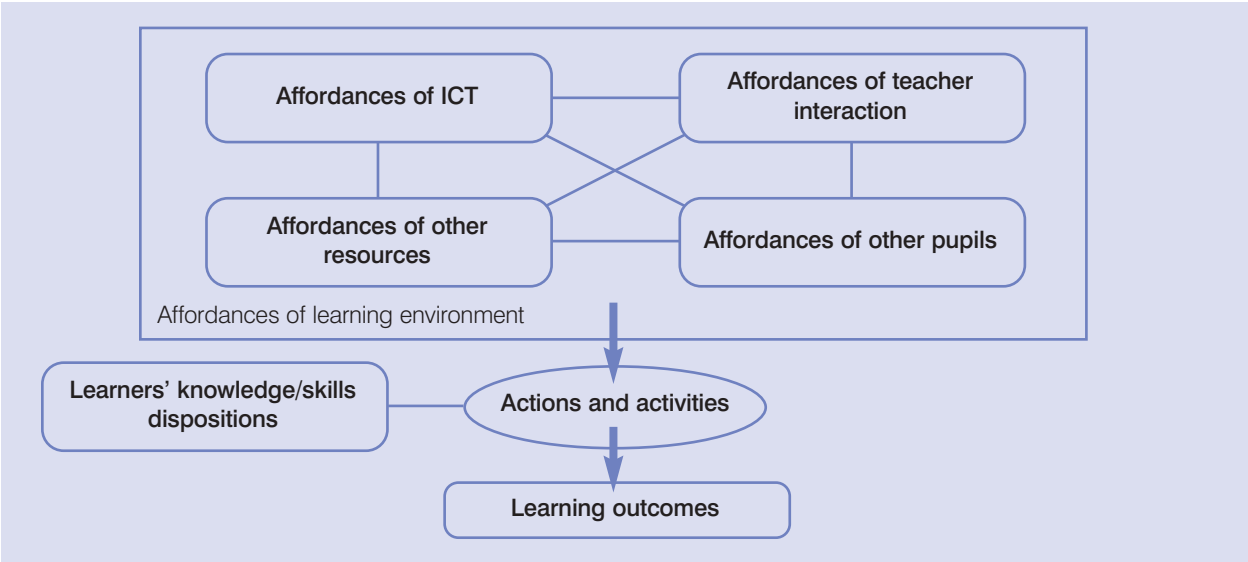


Figure 3.3 – Affordances important to the successful use of ICT

As shown in Figure 3.2, 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 pupils. The pupils provide feedback to the teacher on their understanding, which affects the teacher's ideas about how to improve their explanations.

At the interactive level, teachers are influenced by the discursive interactions with the pupil, which will in turn influence the learning tasks they present to the pupil. These models and others (for example 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 pupils 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 teaching, 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. Consideration needs to be given not only to affordances provided by ICT, but also to those provided by the teacher, the other pupils and other resources, the relative balance of these and their interrelationships; for example peer support may direct pupils towards features of ICT which may then become affordances. Figure 3.3 illustrates these potential interactions.

If one thinks in terms of affordances, activities and learning outcomes, it is possible to characterise the affordances and the interaction between them. For example, in a shared writing activity where 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 3.4. 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 by the network of connections and the subsequent influence on learning outcomes.

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. Pupils' capability with ICT will also affect their capability for independent learning, their meta-cognitive skills, their own perceptions of the learning objectives for a particular lesson 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 software for learning. They suggested the following application skills for graphing software:

- 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, as illustrated in Figure 3.5. What this framework demonstrates is that teachers' knowledge, beliefs and values will affect their pedagogical reasoning. As suggested from the research evidence examined in the previous section, if some teachers believe that when pupils are using an ICT application the teachers should act mainly as 'guides' making few interventions, then pupils' learning may be unstructured and less successful compared with learning with teachers who know the importance of planning and using a structured activity. The beliefs which teachers have about the power and scope of ICT, its new modes of knowledge representation and therefore the different ways in which pupils learn, will profoundly affect the affordances controlling the learning actions and activities.

As shown in Figure 3.5, pupils' knowledge and beliefs affect their behaviour in a learning context, which affects the extent of the affordances which enable them to engage in and benefit from learning. Numerous studies have shown that in addition to the influences shown by the arrows in this 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 also include the fellow pupils with whom each pupil might interact and the intervention and direction of the teacher.

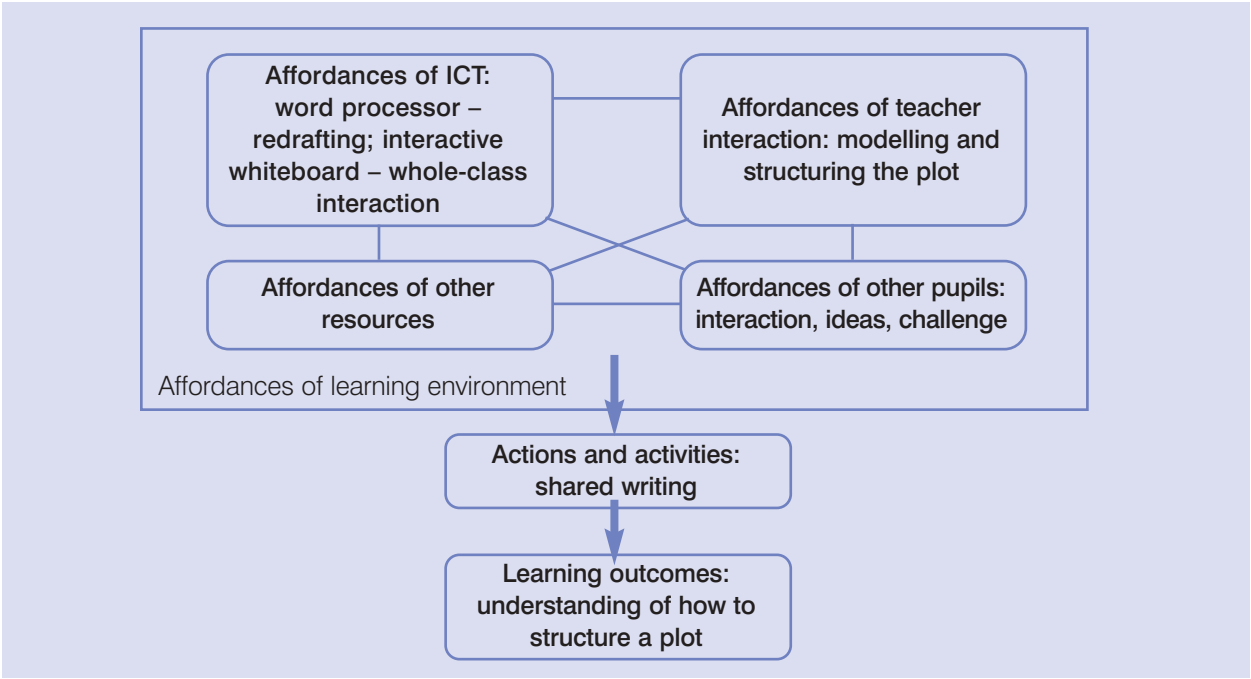


Figure 3.4 – An example of affordances using word processing for redrafting

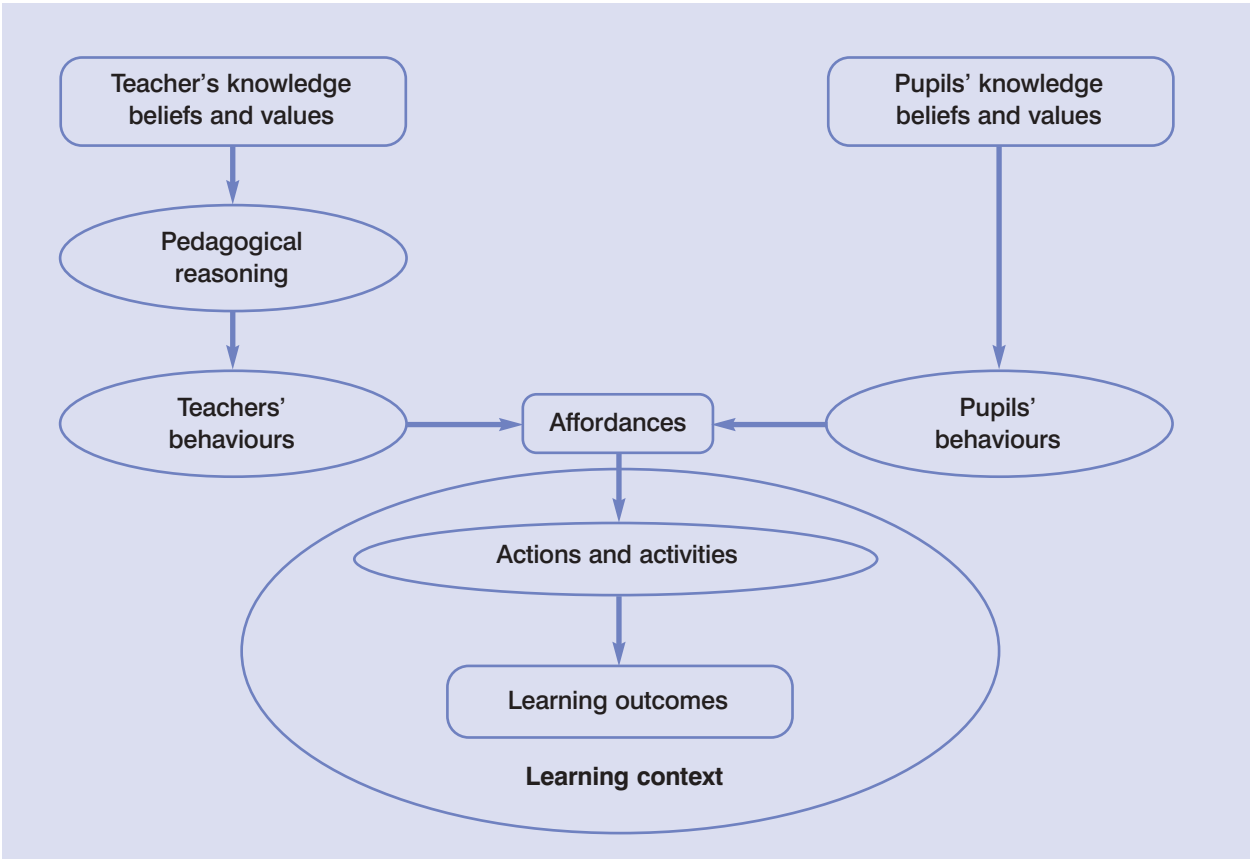
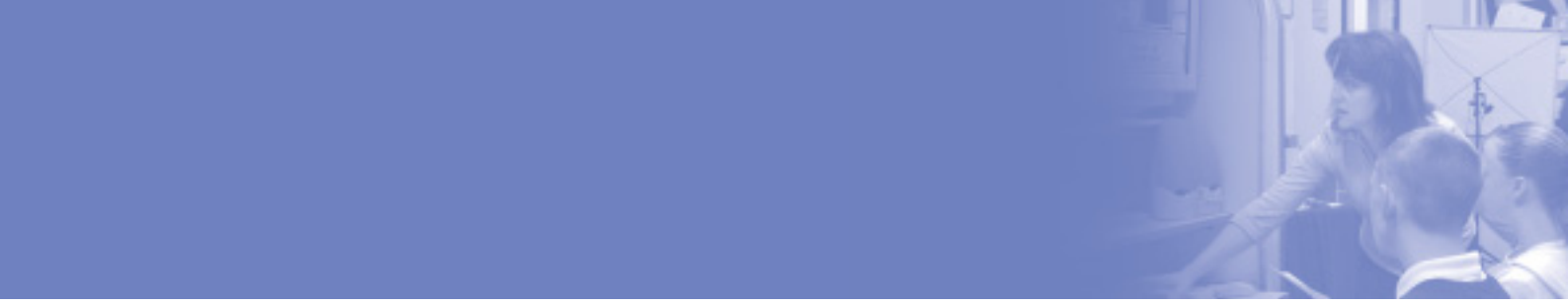


Figure 3.5 – Overview of emerging framework



Section 4 Case studies

For the purposes of this report a small-scale study was conducted of schools known to be using ICT effectively to support attainment, in order to gather additional data and to illuminate the findings emerging from the analysis of the literature.

Approach to the case studies

The case studies focused on individual teachers within these schools. Twenty-six teachers were involved, drawn from six primary and seven secondary schools. These teachers were known to be using ICT effectively to support attainment. The selection criteria were based on evidence of improved learning outcomes for pupils through one or more of the following measures:

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

The case study work involved a questionnaire for teachers, interviews with the teachers, observations of the classes, and analysis of school documents and pupils' work. A more detailed account of the case studies and the procedures used can be found in the full report on which this publication is based (Cox and Abbott, 2004).

Teachers' perceptions of ICT

The first part of this section identifies what the teachers thought were the benefits that ICT can bring to teaching and learning, particularly in terms of pupils' attainment. These insights are drawn from a focus group conducted with a selection of the teachers. This section also identifies teachers' and pupils' current level of skill with ICT.

Advantages of ICT

The teachers considered that ICT can make an important contribution to schools, helping the teaching and delivery of the curriculum in a number of ways:

- ICT can help teachers make the lesson more interesting.
- ICT helps teachers explain things more clearly to learners.
- ICT can be used in most curriculum subjects.
- ICT encourages teachers to vary the ways in which they organise pupils in their lessons, for example computer partners, pairs, larger groups.
- Teachers can prepare for relevant activities beforehand; for example select suitable websites or prepare a folder of images.

An important activity for the teacher is to prepare tasks requiring pupils to demonstrate their knowledge.

Benefits for learning

Teachers reported that the use of ICT had many benefits for learning. One theme which emerged strongly was that pupils could control the learning process and see the results of their actions and decisions. Other specific examples of benefits arising from learning with ICT included:

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

ICT and pedagogy

Level of support for internet searches

The teachers listed a range of activities which they needed to complete when using ICT in lessons:

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

In particular, it was felt that teachers may need to develop greater expertise for activities such as modelling when using spreadsheet software or other modelling software.

Level of support for internet searches

It was agreed that teachers needed to provide a structure for pupils to focus their research when using the internet, and that they need to consider the following points relating to use of the internet:

- The purpose of, and learning objectives for, using the internet need to be considered.
- Many sites have too advanced language for young learners.
- Sites which have more graphics help 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 these issues can be overcome by providing pupils with a list of appropriate websites.

Pupils' attainment

The teachers agreed that it can be difficult to distinguish the effect of the technology from the effect of other activities when trying to determine the impact of ICT on attainment. Different forms of evidence, in addition to tests, can support the claim that ICT helps to improve pupils' attainment. This evidence relating to the use of ICT includes:

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

Primary case studies – key findings

The 10 case studies of primary teachers showed some interesting examples of innovative uses of ICT in primary classes.

Background of the schools

The schools varied in size and in the social backgrounds of pupils as well as the types of ICT resources available. One school had a pupil:computer ratio of 3:1 in a classroom; at the other end of the range another had only 2–3 computers in a classroom. Many of the teachers had access to an electronic whiteboard which enabled them to use ICT for whole-class teaching.

Teachers' ICT skill and experience

Not all the teachers were experienced in all the aspects of ICT that might be required in order 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 their pupils' learning. Although they did not use a wide variety of ICT applications, they were regular users of some ICT resources.

Lessons using ICT

It is clear from the evidence reported here that primary teachers focus on using specific ICT applications and resources regularly in their teaching, rather than 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. A similar pattern was repeated among all the teachers reported here.

Many of the lessons were part of a longer programme of activities, with pupils collaborating and preparing joint work. Several of the teachers saw their role in the lessons as facilitators and advisers rather than as leaders. However, most of the teachers failed to note that their planning of the lesson and scheme of work reflected a leadership role in their pupils' learning. Only when the pupils were engaged in a particular ICT task did the teachers actually move to a more facilitating role.

Practice using ICT

ICT had been incorporated in the practice of these teachers in a wide range of ways. For some, it was through a small enhancement of existing practices using traditional methods, for example a few of the teachers were using an electronic whiteboard instead of a blackboard, which had the additional advantage that they could save their notes for use later. For others, ICT had fundamentally changed the way they taught their subject and the tasks required of pupils; for example two teachers in English and literacy encouraged pupils to film drama presentations, conduct interviews, and then present their work.

Evidence of pupils' attainment and motivation

The different pedagogical practices resulted in different ways of assessing pupils' attainment. These varied from assessing pupils' final written products – using literacy tests, for example – to assessing attainment through pupils' presentations. In the latter case, pupils' knowledge and attainment was measured through their presentation, and through their oral and written skills. Teachers reported increased pupil motivation in many instances. Motivation is hard for teachers to measure, but is clearly an area for further research.

Secondary school case studies – key findings

Among the secondary school teachers there were some similar practices to those of the primary teachers, but the different distribution of ICT resources does appear to affect their practices.

Selecting ICT resources

The case studies support the findings from the research literature which show that the majority of teachers use the ICT resources available, rather than take the initiative of buying ones specifically 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.

Teachers' knowledge of the potential of ICT

The knowledge that teachers had about the scope of ICT resources was influenced by their own ICT competence. For example, those teachers who professed not to have significant experience in using spreadsheets tended to focus on pupils using presentation software to promote class discussion. In such instances the ICT activity centred on presenting knowledge rather than exploring new concepts and processes. As suggested by the evidence from the literature review, this meant that in some cases pupils' learning concentrated on multimedia skills rather than subject knowledge.

Confidence in using ICT

The research evidence shows that teachers' ability to use ICT in lessons is influenced by the confidence they have. All the teachers in the case studies were confident users of their chosen ICT devices and applications. However, they were not necessarily confident in using a wider range of ICT applications. Further, it could be that in some cases when the teachers adopted a facilitator role in relation to ICT, they were expressing a degree of lack of confidence; they were in effect passing the leadership role to the ICT.

Beyond the lesson

Despite the significance of this facilitating role with ICT, a major part of pedagogy lies in the planning, preparation and follow-up of lessons, in which teachers retain a leadership role. None of the teachers in these case studies would have been able to make such imaginative use of ICT in their lessons without careful and appropriate lesson preparation.

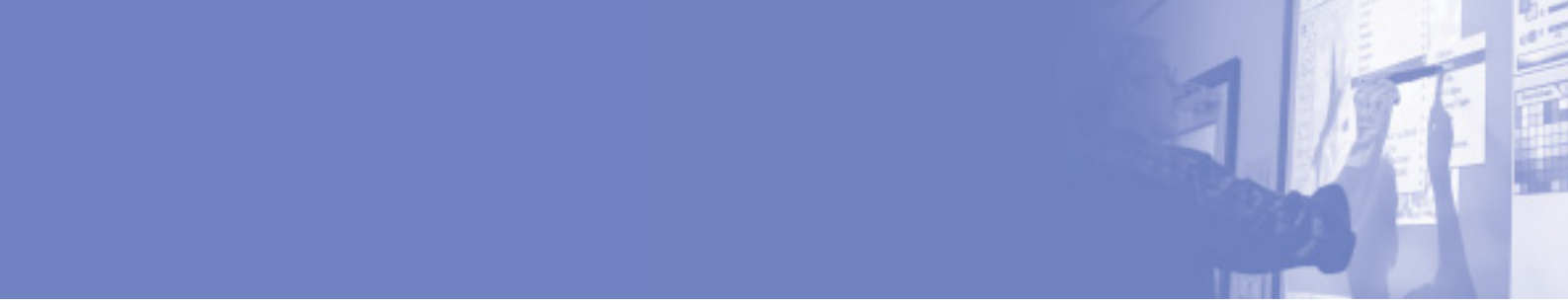
Listening to pupils

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

The teachers emphasised the importance of getting feedback from pupils through written work. For example, one teacher collected printouts of pupils' work at every stage during the designing of their control programs. This teacher suggested that this helped to make her pupils' thinking more visible.

Some ICT packages also enabled pupils to improve their ability to explain specific processes more logically. One teacher claimed that by getting pupils to produce a presentation of a biology experiment, they were then encouraged to provide better scientific explanations of dynamic processes than when, as previously, they had written 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 resources and how they may affect pupils' attainment.



Conclusions

In this review and in the companion report on ICT and attainment (Cox and Abbott, 2004) there is extensive evidence of ICT contributing to improved learning by pupils. The benefits include: enabling pupils to challenge their preconceptions; giving them the means of providing more powerful explanations; helping them develop better reasoning strategies; 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 shows that these benefits are dependent on the way in which the teacher selects and organises the ICT resources, and how this use is integrated into other activities in the classroom and beyond. The crucial component remains the teacher and their pedagogical approaches.

Examples of the specific uses of ICT most frequently reported in the literature 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.
- Interactive whiteboards to promote class discussions, and pupils' explanations and presentation skills.

Teachers' pedagogical approaches are in turn affected by a number of key factors.

First, they are affected by knowledge about their own subject. There is a clear distinction between teachers who choose ICT resources to fit within a particular topic and those who choose resources merely to present pupils' work in a new way, without any direct application to the topic. The evidence shows that when teachers use their knowledge both of the subject and also of how pupils understand the subject, their use of ICT has a more direct effect on pupils' attainment.

On the basis of the research evidence and the case studies conducted for this study, there appear to be three main approaches to ICT taken 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 an electronic whiteboard for presenting theory about a topic. In this approach, the teacher plans to complement the lesson with an innovative presentation method to promote class discussion and the visualisation of problems.
- Complementary approach: using an ICT resource to empower the pupils' learning, for example by enabling them to improve their class work by taking notes on the computer, or by sending homework by email to the teacher from home, or by word processing their homework.

All three approaches can enhance attainment, but the effects may be different. In the integrated approach, pupils' learning is enhanced because they are confronted with challenges to their existing knowledge and given deeper insights into the subject being studied. The enhancement approach could improve pupils' learning through presenting knowledge in new ways, promoting debates among pupils, and encouraging them to formulate their own explanations. The complementary approach draws on the approach that suggests that learning can be enhanced by reducing the mundane and repetitive aspects of tasks such as writing essays and homework by hand, freeing the learner to focus on more challenging and subject-focused tasks (see Kemmis *et al.*, 1977).

These different types of 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. Mayer-Smith (1998) investigated the relationship between computers and views of mathematics from both individual constructivist 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 view that computers alter the way we do mathematics. Individual constructivists – 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 by using an electronic whiteboard to demonstrate problems on the screen and stimulate class discussion (the enhancement approach), while other teachers would choose ICT modelling to extend the mathematical models which pupils can construct and investigate (the integrated approach).

Obviously, access to ICT resources is another key factor. The majority of teachers use the ICT resources available rather than take the initiative of buying ones relevant to their own subject. This can result in pedagogy being determined by ICT resources rather than by the teacher and the subject. For example, many teachers report using electronic whiteboards which were purchased for the whole school. Only a few teachers report using subject-specific software which links directly to the content of the curriculum. It may be that many teachers accept the uses of ICT imposed on them by senior management. This also influences the research that is carried out. Naturalistic studies – that is, those studies that investigate how teachers use their existing ICT resources – are often only able to focus on a limited range of uses. This has meant that many researchers have had to introduce specific ICT resources into a school in order to study the effects of ICT use, which can influence teachers' attitude to and uptake of the resource.

In spite of teachers often being limited by the ICT resources available to them, there are many examples in the research literature of teachers having a good understanding of a particular resource. This can be influenced by the way in which ICT relates to their subject. Science teachers report that their main use of ICT is for simulations and modelling, whereas English teachers tend to use word-processing and presentation software. These teachers' use of ICT may be quite regular, but only rarely includes the use of other applications which they are less familiar with. It is clear that teachers' confidence affects which applications they use, even among those teachers who gained a degree of confidence using one or two familiar applications.

This lack of confidence may result in some teachers adopting the role of facilitator, when the research evidence suggests that the role of the teacher in organising classroom activities remains crucial. One example concerns the benefits of collaboration between pupils.

Pupils using ICT in pairs, in groups or as a whole class, through the use of an interactive whiteboard, can provide explanations of topics, which enables teachers to monitor their progress. Although such work takes place without the use of ICT through, for example, group work in primary schools and laboratory work in secondary schools, there are many reports of pupils understanding being improved through them having to make their explanations explicit and by sharing them with others. There is also evidence, however, from a number of studies, which shows that if pupils are put in pairs or groups but their learning tasks are not planned on this basis, then no additional benefit for pupils' attainment is achieved.

If ICT is to have a positive effect on pupils' attainment, then the technology should support the underlying instructional approaches. The effective use of ICT should not mean the absence of organised structure; rather, effective use relies on structure in order that pupils can develop their own meaningful representations of knowledge using ICT.

The overall conclusion from the research literature is that ICT is used effectively and has an impact on learning where teachers are able to appreciate that interactivity requires a new approach to pedagogy. Teachers need to employ proactive and responsive strategies in order to support, guide and facilitate learning. They need to monitor progress and maintain a focus on subject learning, by structuring activities carefully and providing focused tasks. It may be that there is a fundamental misunderstanding held by many teachers and teacher trainers – teachers who have insufficient knowledge of the contribution which ICT can make to pupils' learning can assume that the main tasks are to familiarise themselves with the software, prepare a worksheet for pupils to show how to operate the program, and then use the program in their lesson. But a major part of effective use of ICT lies in the planning, preparation and follow-up of lessons, and in particular the pedagogical thinking that links teaching style, the selection of resources, the activities and the learning objectives.

It is clear from this research that in order for the majority of teachers to extend their range of uses of ICT substantially, they need significant time to develop their pedagogy as well as their ICT skills. Given the limitations on resources and the demands on teachers' time, this may be difficult to achieve in the foreseeable future. An alternative approach might be to encourage teachers to focus only on those ICT resources which are most relevant to them and their subject.

Priorities for the future

Although it is clear from this study that there is now a substantial body of research into the use of ICT in education, there is much research still to be done to map the specific relationships between teachers' use of ICT and the effects on pupils' attainment.

There are some broad principles for future research. First, in order to evaluate the relevance of the lesson activity to the subject being taught, researchers should have relevant subject knowledge. Secondly, researchers need extensive knowledge of the ICT resources being used in order to develop measures of the learning which might be promoted by the resource.

Many researchers have measured teachers' pedagogical practices by observing and recording lessons in which ICT is used, in order to identify the actions of the teacher and the teaching strategies which they adopt in their lessons. However, some studies have used this approach without capturing the pedagogical reasoning behind the teachers' practices, or recording the preparation and planning prior to the lesson, so weakening the chain of evidence between pedagogy and attainment. It is also useful for researchers to collect related materials such as lesson plans and pupils' work for this purpose. More generally, future research must recognise that teachers and pupils work within very specific contexts (subject, topic, learning objectives); the influence of this context needs to be appreciated.

One aspect of this context which has been neglected is the influence on their colleagues of teachers who are more experienced in using ICT, in terms of pedagogical reasoning and practice. In addition, while there have been many studies investigating the effects of teacher training on the uptake of ICT by teachers, little is known about the relationship between their experiences within professional development and their subsequent pedagogies when using ICT. Another aspect, which is often left out of comparative research studies, is the collection of data from classes with the same or different teachers who are not using ICT. This would help better identify the forms of pedagogy specific to ICT, or rather particular forms of ICT.

Further, teachers' pedagogical practices with ICT can vary over time with the class of pupils they are teaching (as shown in the first ImpacT study (Watson, 1993)), both as a result of learning more about the ICT resource and their pupils' skills, and also because some topics in the syllabus are more suitable for using ICT than others. As a result, researchers who have observed the same teachers over a longer period have been able to obtain a more comprehensive picture of their pedagogical practices than those who only observe one or two lessons. Yet research over long periods has been relatively rare. For this reason, and to understand the longer-term impact of ICT on classroom practice, more evaluations covering two to three years are required.

The most important guiding factor is to match the methods to the research aims. In the case of ICT and attainment this means the factors shown in Figure 3.5.

Comparing the evidence of teachers using ICT in schools 20 years ago with that available today, it shows that there is a steady growth of innovative and experienced teachers able to use ICT to improve their pupils' attainment. What is needed now is a way of helping more teachers and pupils benefit from these opportunities and experiences.

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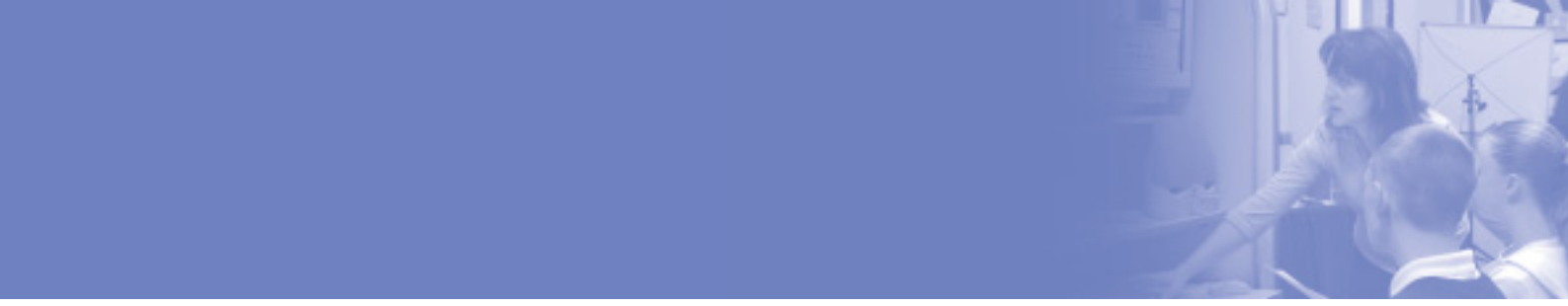

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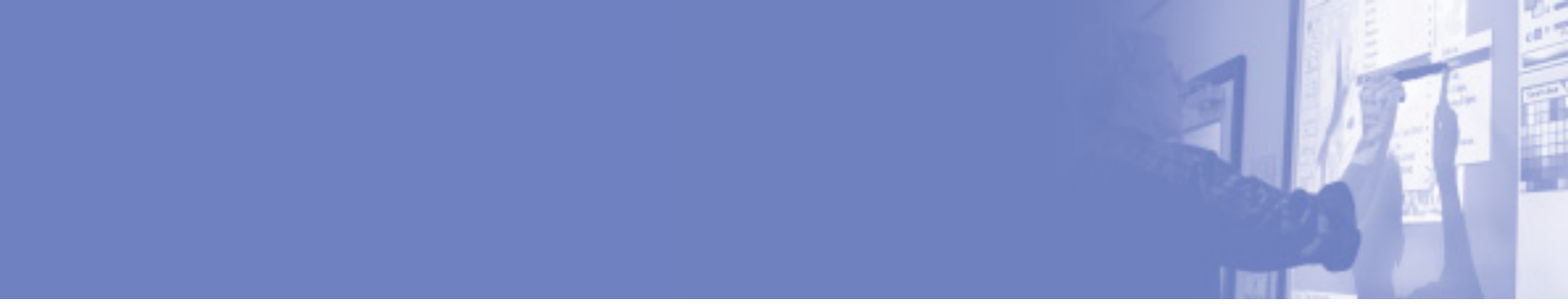

The ICT in Schools programme is central to the Government's ongoing programme of school reforms. *Fulfilling the Potential,* launched by the Secretary of State for Education and Skills in May 2003, outlines future directions for ICT as an enabler in whole school development and teaching and learning. Copies of *Fulfilling the Potential* are available on www.dfes.gov.uk/ictinschools. Research and evaluation is being undertaken using a variety of techniques, both qualitative and quantitative, and at both national and local level.

Below you can find a list of the reports published so far in the ICT in Schools Research and Evaluation series, produced by Becta for the Department for Education and Skills (DfES).

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Westminster
London
SW1P 3BT

ISBN 1 84478 135 6
DfES/0793/2003

Produced by Becta for the Department for Education and Skills

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