Research Report No. 03/1

Pedagogic Strategies for Using ICT to Support Subject Teaching and Learning: An Analysis Across 15 Case Studies

Sara Hennessy, Rosemary Deaney and Kenneth Ruthven

University of Cambridge
Faculty of Education

17, Trumpington Street, Cambridge CB2 1QA Telephone: 01223 330569
email: sch30@cam.ac.uk
http://www.educ.cam.ac.uk/

Table of Contents

Pedagogic Strategies for Using ICT to Support Subject Teaching and Learning: An Analysis Across 15 Case Studies

Sara Hennessy, Rosemary Deaney and Kenneth Ruthven

Summary

This research investigated teachers' and pupils' changing roles and strategies in the context of using various forms of computer-based information and communication technology (ICT) to support subject teaching and learning at secondary level. 15 teacher-researchers participated in a collaborative programme of small-scale, classroom-based projects involving development, trialling and refinement of new pedagogic approaches, strategies and activities in six curriculum areas. An analysis was conducted across the case study data derived from lesson observations, follow-up teacher interviews and teachers' written research reports.

Using ICT was associated with a decrease in teacher direction and exposition, a corresponding increase in pupil control and self-regulation, and more pupil collaboration. These changes in classroom practice meant that teachers felt they needed to employ proactive and responsive strategies in order to support, guide and facilitate learning, to monitor progress and maintain focus on subject learning, to encourage pupil reflection and analysis, to structure activities carefully and provide more focused tasks, to pace lessons realistically, and to support learning and revision by making available printed and other written resources. Simultaneously, teachers strove to encourage and support pupils in taking a greater degree of responsibility for their own learning through increased participation.

It was recognised that developing new pupil skills for information handling and critical analysis is necessary, although the teacher's role in this was not consistently perceived. While interactions with individual pupils and small groups were increased and reportedly successful, mediating interactions between pupils and technology through whole class interactive teaching, modelling and discussion appeared to be under-developed at present. Use of these strategies is expected to increase as availability of projection technology becomes more widespread and would further facilitate the important processes of analysis, reflection and consolidation of subject learning. In sum, an extensive range of successful strategies was employed (many of these building on established practice), yet the pedagogy associated with using ICT to support subject teaching and learning is still evolving.

Introduction

The important mediating role of the teacher has long been established in the educational research literature. A neo-Vygotskian perspective is particularly informative about the ways in which teachers create conditions generative of active – and ultimately independent – learning activity, and mediate the interaction between child and environment; this process includes both guided and collaborative activity, within and outside the context of formal schooling (Kozulin, 1998, Rogoff, 1995). The increasing availability of computer-based tools and resources and the growing emphasis on using these in subject teaching and learning has a potentially significant impact upon established classroom practice. Although the process of pedagogic change associated with integrating use of educational technology seems to be evolutionary rather than revolutionary (Cuban, 2001, Hennessy et al., submitted, Kerr, 1991), a perceptible, gradual shift is taking place in teachers' and pupils' roles and strategies in their efforts to make effective use of ICT. These changing roles and pedagogic strategies are the concern of this paper.

Development of appropriate pedagogy for integrating use of ICT in subject teaching has lagged behind the massive investment in provision of hardware, software and teacher training in using ICT (Newton & Rogers, 2001). The pressing need for robust knowledge of this kind has been noted by Becta and others (e.g. Lynch, 2001, Ofsted, 1999). Much research into classroom use of ICT has been carried out in innovative schools with 'technology-rich' classrooms or in highly subject-specific contexts. Moreover a recent meta–analysis of over 600 studies confirmed that the research tends to focus on students' interaction and learning with ICT rather than the role of the teacher in instructional design and classroom organisation (Lagrange *et al.*, 2001). It is particularly rare to find teachers as active participants in this research. This literature nevertheless provides some basis for comparison with our own work.

Three American studies are particularly relevant. The most recent by McGhee and Kozma (2001) categorised the new teacher and pupil roles emerging in six innovative schools, in using technology effectively to support project- or inquiry-based learning. Teacher roles identified were: instructional designer, (technical) trainer, enabling advisor/facilitator, monitoring and assessment specialist, team coordinator and collaborator. The latter two are largely irrelevant to classroom work in a typical British school context where teachers do not normally encounter opportunities for project-based learning or team teaching (although members of subject departments usually collaborate when integrating ICT into a departmental scheme of work). Associated pupil roles of self-learner (active and autonomous), team member and knowledge manager were also identified. These findings resemble those of Means and Olson (1997) who carried out case studies of nine US schools or programmes nominated as innovative in using ICT within the curriculum, and with another American study by Hadley and Sheingold (1993) who surveyed teachers who had integrated ICT into their practice. The latter concluded that "many of these teachers [reported] that integrating the computer has turned a teacher-centred classroom into a student-centred one, with the teacher acting more as a coach than information dispenser, and with more collaboration and work in small groups going on" (p.277). However, Means and Olson (1997, p.132) warn that developing new pedagogical approaches – and technological skills – is energy-intensive and highly demanding on teachers, particularly where these represent a change from previous practice. Indeed research shows that teachers who are successfully integrating ICT into subject teaching tend to be teachers who already have an

innovative pedagogic outlook (e.g. the ImpaCT2 interim report[1]) so that these findings are not necessarily generalisable to the typical classroom. To summarise, teachers using computers increasingly see themselves as facilitators of learning, although this depends on levels of provision and use of technology, and also on pre-existing patterns of teacher-pupil interaction, especially 'coaching' behaviours (Schofield, 1995, ch.7).

A complementary – and commonly occurring – theme in the literature is the perception of pupils as becoming more independent, active and responsible learners and one of the aims of this paper is to investigate the implications of this for pedagogy[2]. Since digital technology has rendered the production and organisation of textual, numerical and graphical information more provisional and fluid, the belief that ICT-based activity lends itself to open-ended, exploratory learning with opportunities for pupil reflection, experimentation, manipulation, explanation, interpretation etc. is plausible. However independent 'discovery learning' approaches have long been discredited (unguided experimentation with LOGO proved unproductive in the early 1980s) and effective pedagogy for supporting these kinds of learning with ICT is currently under-developed. Indeed, haphazard, unproductive or routinised uses of ostensibly interactive forms of ICT are still observable (Ellis, 2001, Newton & Rogers, 2001); accessing electronic data does not necessarily involve engaging learners in active processing and restructuring of information, and simulations can make too few demands on pupils (Ofsted, 2001). In the absence of appropriate teacher guidance, software applications can become the curriculum itself rather than tools for problem solving, research and knowledge creation (Cognition and Technology Group at Vanderbilt, 1996). There is a potential tension between the desire to offer – and increase – pupil participation and autonomy, and the belief that teacher guidance and intervention, appropriately pitched activities, rigorous advance preparation, tightly defined lesson objectives, carefully structured tasks and clear deadlines are also necessary (Finlayson *et al.*, 2002). Finlayson *et al.* (p.11) conclude that both are desirable: "A culture of student-centred learning, mediated through strategic teacher interventions, is associated with beneficial experiences with ICT. Many successful teaching episodes depend on thorough preparations beforehand, linking the ICT to ongoing teaching and learning rather than using it in isolation" (e.g. linking the products of Web searching with other class activities before, during and after the computer–based lesson).

In exploring these two interwoven aspects of classroom interactions, we draw on Rogoff's framework for analysing interactions in terms of 'guided participation' in sociocultural activity (Rogoff, 1990). In this account, the adult subdivides tasks into manageable goals and gradually increases the child's participation and responsibility for activities. Support and guidance are given both in tacit and explicit forms, and provide both challenge and sensitive assistance. In the classroom, we can view the teacher as managing pupil participation through constraining or channelling learning activities, although ideally the support provided is more responsive to the learner than directive (Anghileri, 2002). According to Rogoff, children take a significant, active role in structuring instruction through simultaneously adjusting their level of participation and requesting assistance, greater responsibility and involvement. We assess how useful this perspective is for analysing teacher-pupil interactions in the context of classroom ICT use. Our earlier research confirmed pupils' desire for teacher support within a context of

[1] ImpaCT2 is a DFES/Becta large-scale longitudinal study of ICT and student attainment: www.becta.org.uk/impact2.

[2] Our use of the term 'pedagogy' incorporates the complex relations between teacher, learning context, subject knowledge, purposes, teacher's view of enhancing learning, selection of learning and assessment activities, learning about learning, and learner characteristics such as age and knowledge (although this is not necessarily the same as the model that teachers tend to hold, which simplifies the relationship between pedagogy and learning: Watkins, C. & Mortimore, P. (1999) Pedagogy: What do we know?, in: P. Mortimore (Ed) *Understanding Pedagogy and its Impact on Learning* (London, Paul Chapman)..

more independent working; here we investigate whether and how the teacher plays a critical role in selecting learning resources and framing these to exploit ICT in pursuing learning goals; in structuring, sequencing, pacing, monitoring and assessing learning with ICT (Bruner, 1985, Noss & Pachler, 1999, Scrimshaw, 1993, Selinger, 2001). In addition, we examine the role of teachers in mediating interactions between children and technology – supporting learning through interpreting processes, discussing and explaining meaning, and creating a classroom climate which fosters productive pupil talk and reasoning (Mercer, 1995), as they do when using other resources.

Another key feature of the teacher's emerging role is to foster development of new pupil strategies and skills – both creative and exploratory – for knowledge creation and application (rather than building a fixed knowledge base which can quickly become outdated). The new skills and understandings required focus on the processes of learning rather than on its products and two prominent examples move away from transmitting and memorising information towards helping children find, extract and make sense of it:

- *'information/digital literacy':* developing an awareness of resources available and how to frame research questions; the ability to locate, retrieve, exchange, develop, combine, interpret, summarise, edit, filter, manage, publish or present information in a variety of forms (e.g. textual, graphical, numerical), to identify connections and use information in a range of contexts (e.g. Loveless et al., 2001, Scrimshaw, 1997) the Key Skills Units and assessments for Information Technology (QCA/DfEE, 1999) are entirely concerned with information literacy, involving electronic and other sources).
- *'critical literacy'*: combating high face validity of computers, anonymity and potential lack of authority of authors (especially of Web-based material), inaccurate representations, contradictory information and undesirable impacts on learning and understanding, with an awareness of where information has come from, how it got there, who put it there and why (Collins *et al.*, 1997) and the ability to select appropriate information.

(Note that these literacies are closely inter-connected; the second is perhaps more 'higher order' but it depends on having mastered the first. Nevertheless they are often described separately in the literature and by teachers, so they are treated differentially here.) Despite increasing recognition of their critical importance (e.g. Hammond, 2001), there is little indication that schools are strategically tackling these pedagogic issues yet. Recent evidence from Ofsted (2001) indicates that pupils lack strategies for obtaining ICT-based information efficiently, they are not yet moving beyond the location of information as an end in itself and they continue to present unprocessed information. Teachers thus need to help pupils develop "much more sensitivity, determination and understanding to handle large volumes of potentially relevant information, as well as strategies for focusing on the most useful material for the purpose in hand" (*ibid.,* p.10).

The research literature also indicates that *collaboration* between students (and modelling for peers) is becoming a key feature of educational technology use, particularly because machines are often shared. In fact, since the late 1980s, a growing body of favourable research evidence has accumulated for the cognitive benefits of technology-supported collaborative learning and problem solving in many subject areas (e.g. O'Malley, 1995). It must be stressed that genuine collaboration means much more than the spontaneous sharing of information and technical expertise – and the increase in cooperation and task-related talk – typically observed, even when children use individual forms of digital technology (e.g. Bowell et al., 1994, Schofield, 1995). It is certainly more than dividing the task and/or sharing computers through turn taking (typically in pairs), a situation often forced through lack of hardware resources rather than educationally motivated. The term collaboration reflects the notions of a shared frame of

reference regarding task and purpose, a joint outcome, and discourse characterised by the explicitation and negotiation of ideas and joint decision making. This is elaborated by Hennessy & Murphy (1999) drawing on sociocultural perspectives such as Rogoff's (1995) notion of learning through changing participation, which encompasses peers serving as both resources and challenges for each other and resolving conflicts. Technology can play an important role here in offering a stimulus and a medium for talking about and refining constructions (as exemplified by (Barton, 1997, Hennessy et al., 2001, Noss & Hoyles, 1996). Yet, using ICT is often perceived as encouraging an 'individualised' learning approach (e.g. Goodson & Mangan, 1995). There is also limited appreciation that specific skills for collaboration – including explaining, justifying, negotiating and feeding back – need to be deliberately fostered through continuous, targeted teacher support in the context of purposefully designed tasks (Hennessy & Murphy, 1999, Scrimshaw, 1997) and a conducive physical environment (e.g. Schofield, 1995). Students unused to working collaboratively find it very difficult. (The 'ImpacT Report' confirmed that use of ICT was more effective where teachers accepted that pupil collaboration was an important aspect of classroom practice: (Watson *et al.*, 1993). (Means & Olson, 1997), similarly noted that classrooms where collaborative skills were a focus and were given explicit training benefited most from using ICT collaboratively.) In sum, the teacher plays a critical role in fostering and supporting pupil collaboration as a vehicle for subject learning, especially where this is a new way of working for the pupils in their classroom.

To conclude, there is a rhetoric of educational reform emerging from the research literature which envisages a transformation of the roles of the teacher from 'sage on the stage' to 'guide on the side' (origin unknown) and of the pupil from 'sponge' to 'creator', 'explorer' or 'decision maker' (Loveless *et al.*, 2001). In this study we examine the reality at what was the chalkface, but could now be construed as the evolving interface between pupils and digital technology. Are teachers becoming facilitators of independent, investigative learning, making sensitive interventions according to children's technical expertise and cognitive needs, in a context of genuine peer collaboration (cf. Moseley *et al.*, 1999) – or are they more often in fact technical troubleshooters for pupils who spend long periods waiting for a turn at the machine and for teacher support? Our analysis centred on these interlinked questions:

What pedagogic strategies are emerging for using ICT successfully, i.e. how do teachers feel that they create the conditions which generate and support learning with these tools?

How are the roles of teachers and students changing in this context, and what new strategies do they engender?

This paper complements previous research accounts by examining changing pedagogy through analysis across a set of in-depth classroom case studies, carried out in partnership with teachers researching and developing their own practice, across a range of curriculum subjects, and in the cultural context of mainstream English secondary schooling (as elaborated below).

Context

This study formed the main phase of a wider research project which was endeavouring to increase the meagre evidence base of research in this area by analysing, developing, refining and documenting effective pedagogy for using ICT in subject teaching. A prior formative phase involved focus group interviews with core subject departments and pupils, eliciting their thinking about the ways in which ICT use can support subject teaching and learning (Deaney et al., in press, Hennessy et al., submitted, Ruthven et al., submitted). The findings confirmed that while teachers are motivated to integrate appropriate uses of ICT into their classroom practice, pedagogy for effective use has not yet been clearly established. Similarly, an interview study

by Williams *et al.* (2000) found that teachers were still in the early stages of ICT development regarding integrated use of ICT and they expressed a need for more knowledge on how best to apply ICT in the teaching and learning context.

The educational context of this research is as follows. Use of what is now known as ICT became a statutory requirement with the introduction of a National Curriculum in 1989. The obligation placed on schools was further elaborated in 1995: "Pupils should be given opportunities, where appropriate, to develop and apply their IT capability in the study of [other] National Curriculum subjects" (DfE, 1995, p.1). Since 1998, around one billion pounds have been spent by the British government on ICT initiatives, including extensive training schemes. However, there remains a lack of guidance and support for practitioners in incorporating ICT in subject teaching in appropriate ways directly related to the prescribed curriculum (Selwyn, 1999b), which in any case still offers only a handful of opportunities for using ICT within the core subjects (DfEE, 1999). At the time of the study, appropriate and effective classroom use of ICT was considered to be rare (Ofsted, 2001) and there were many obstacles. Hammond (2001) reported that virtually all secondary schools had some level of connection to the Internet but the unreliability of the technology, insufficient training and support for teachers, uncertainty about pedagogical relevance, and time pressures hindered regular and effective use. In the face of such adversity, we were fortunate to recruit a significant number of teachers working in a variety of settings who were motivated to develop their practice in using ICT in the classroom.

Methods

Participants

The main phase of the project took the form of a collaborative programme of small-scale, classroom-based projects investigating a range of technology-integrated pedagogical strategies. The participants were 15 volunteer teacher-researchers from 5 maintained (non-selective) secondary schools. The schools formed part of a research partnership programme with the University of Cambridge Faculty of Education, through which research-based processes of school improvement and professional development were being explored. The schools were located within a 50-mile radius of Cambridge and, by standard indicators[3], were relatively socially advantaged and academically successful. There was some variation in ICT provision amongst the participating schools – the most highly resourced school having specialist Technology status – but ICT use within subject teaching and learning mostly depended upon opportunistic access to computer rooms that were already heavily scheduled for other purposes. In this study only the teachers of Science and Design and Technology had access to departmental ICT suites.

The participating teacher-researchers were aided by small grants[4] intended to fund support for their work – typically provided by a colleague in each school acting as local coordinator for the school-university partnership programme, the associated university team and an allowance for participants of up to 10 days release from normal duties (although staffing pressures meant that most were unable to secure as much time). Not all of these teachers already had an innovative pedagogic outlook or established expertise in integrating the use of ICT in classroom teaching

[3] Standard indicators taken as follows: for social disadvantage, the proportion of students entitled to free school meals; for academic success, the proportion of students gaining the benchmark of 5 or more higher grade GCSE passes (grades A-C) at age 16.

[4] Most participants were in receipt of Best Practice Research Scholarships [BPRS] awarded by the national Department for Education; a small number were supported by equivalent grants from the Wallenberg Research Centre for Educational Improvement in the university Faculty of Education.

and learning, but all were keen to develop their practice in this arena. Pairs of teacher-researchers within the same department were encouraged to work collaboratively on case study projects; 5 collaborative and 5 individual projects emerged.

Focus and support of case study projects

The main phase of the programme took place over the 2000/01 school year. Although the projects proposed all built to some degree on teaching and learning approaches already in use, they typically involved significant development of the role of ICT within these approaches. Participants were organised into groups of between 3 and 5 members pursuing similarly themed projects across schools; these covered six curriculum areas and involved pupil groups from Years 7-13 (see summary provided in Table 1). Preparation of teaching and research plans was supported by each group meeting with the university team on five occasions during the year. As well as discussing their evolving plans at these meetings, groups received presentations from the university team suggesting ideas and approaches which might be helpful in executing and writing up their projects. Draft reports received feedback from the university team before final submission[5].

Investigative strategy

At an appropriate point, each participant was visited in school by a member of the university team who observed a lesson. Observations focused on teachers' and students' roles and ways of using ICT in the specific setting. The lesson was followed directly by a 2-minute interview – inviting teachers' immediate feedback on the lesson – and subsequently by an extended, semi-structured, post-lesson interview intended to stimulate a grounded account of teachers' thinking about their (current and future) practice and specifically about the contribution of ICT use to success of the lesson. Observations and interviews were audiotaped; lesson plans, activity sheets, samples of student work and digital photographs provided additional records to complement the researcher's observation notes and pen-portrait depicting classroom setting and activity. Observation records and interview transcripts were returned to participating teacher-researchers for corroboration.

Cross-case analysis

The situated perspective (e.g. Rogoff, 1995) highlights the ways in which teachers' thinking and practice are embedded in particular settings, and these are detailed in the individual case study reports by the teacher-researchers. In order to move beyond these, however, we conducted an overarching analysis which explored complementary and alternative perspectives across cases and was ultimately aimed at identifying some transposable pedagogic practices and strategies. Thus, the findings are described at a general level but they are grounded in clearly documented specific settings and practices, some of which may be subject-specific. (Subject cultures may influence pedagogy related to using ICT (Goodson & Mangan, 1995, Selwyn, 1999a) but this was not the focus of our analysis here.

The analysis drew on case study reports to provide contextual material and on lesson observations for snapshot views offering detailed examples of teaching practices and episodes, illuminated through post-lesson interviews. Lesson observation and interview data were collated and summarised for each of the 15 case studies; where pairs of teachers worked together, similarities and contrasts of approach were noted. Initial scrutiny of interview transcripts suggested a number of broad themes from which more detailed codes were subsequently derived. Summarising sentences were added throughout the transcripts,

[5] The full reports are available on the TiPS website at <http://www.educ.cam.ac.uk/TiPS/tips1.html>.

segmenting the text and highlighting changes in focus of talk. Corroboration of emerging themes was provided by referring back to preceding observations to illustrate the interview data in each case. To minimise bias, counter-examples were sought and data were analysed by two researchers working independently; summaries and conclusions of each case study were validated by the original observer and later by subject specialists within the Faculty. Interview transcripts were imported into a computer database (QSR NUD*IST) and thematic codes applied in a process of systematic, recursive comparison (Glaser & Strauss, 1967) themes and sub-themes were examined across the 10 projects.

Findings

Changing roles of teachers and pupils – and mediating strategies for successful use of ICT

As might be expected, our classroom observations and teacher interviews indicated that many facets of the teacher's usual role and extensive repertoire of pedagogic strategies were evident in lessons using ICT. These included: questioning, prompting, intervening, guiding, explaining, suggesting, eliciting reasoning, introducing, reviewing and summarising, motivating, encouraging and praising, giving feedback, keeping pupils on task, supporting individuals, pacing and monitoring progress, demonstrating procedures, facilitating discussion (with class/groups/individuals), challenging and adapting to different abilities. While these established strategies are not specifically related to ICT use and are consequently not elaborated in any detail, they clearly remain important in this context. However, there were some notable, explicit differences in teachers' and pupils' roles and interactions, teaching styles and mediating strategies compared with the teachers' reports of lessons without ICT, and these are now explored.

The most significant change reported by some teachers – although anticipated by few – was a *decrease in teacher direction* through formal didactic teaching and knowledge giving, when ICT was used (DR, AY, OT, FC, RA, VM). This meant that teachers employed less 'spoon feeding':

> The only time you really input is if a student can't remember or doesn't totally understand and so you just reiterate it with them, whereas teaching the orthographic by hand, you just stand at the front and you go step-by-step through, and once the drawing's completed, they never do it again. So they are not really learning the commands, as it were… that is when you spoon-feed them. (JN)

There was considerable evidence instead of more *involvement* and discussion between the teacher and individual or small groups of pupils, and of teachers *facilitating* rather than directing activity, as elaborated below (AI, DR, FC, OT, KE, RA, VM, OL/AY report). Six teachers recounted how they circulated methodically around the class and interacted with more pupils when using ICT; for example, "it was a lot easier to go round... I managed to focus on every pair of children" (DR). This teacher described how some children's ideas and actions can be overlooked under other circumstances: "I marked their books last night and there was a row of… four girls who came up with this idea and I hadn't seen it during the lesson". One English teacher explained the increase in task-related interaction between teacher and pupils in terms of her requirement for pupils to work alone and in silence when writing by hand, in contrast to her expectation when pupils were working together at the computer:

> I wouldn't actually interact with them so much… I think in there I actually looked at every single pair… it generally would be a lot quieter, a lot more formal, writing on their own, me not talking to them, it'd be quite dull really. (AI)

The most common rationale for this pedagogic shift was that the decreased emphasis on formal teaching and intervention when using ICT allows more time to be spent in productive

interactions with students; it frees the teacher to offer more *support, guidance and facilitation* – the prominent mediating strategies associated with using ICT:

> I suppose that's the key one, the idea of taking more of a back seat and being the facilitator… (RA)

> I took a larger role in their decisions… I was perhaps with them a little bit more often, walking round constantly. (DR)

Some teachers described their role during the lesson in terms of introducing the task, then focusing the pupils. For example:

> I needed to instigate the ideas, I needed to prompt them firstly about what we were doing. I wouldn't say I was a teacher, in the conventional sense anyway, certainly once the lesson… was progressing, I was more looking just to try and focus them on particular aspects. There was certainly no formal teaching, never intended to be. (OT)

> I was there to keep them focused on the task and help out in terms of giving them information that they'd perhaps forgotten or clarifying details of the text, those kinds of things, but it was pretty much self-generating. (AI)

Using ICT for self-regulated learning was not considered to diminish the teacher's intervening role. In some ways, this remained the same – for example, reminding pupils to research their facts fully, as they must when using textbooks (DR), and in other ways, new aspects of this role evolved:

> I think you need to be quite active in the classroom… keeping them on task, because I think it's very hard to anticipate the slightest little alley ways and by-ways that they might take, so… although in theory it would be lovely to create these lessons where you just press start and relax, it's not going to be like that unless you have some way of limiting their access to all these things. (RE)

The more supportive and facilitative teacher role was continually contrasted with that of the traditional knowledge giver. One teacher described the new role as more one of helping children find information for themselves, with prompts but largely under their own control; but then subsequently commented in the light of experience that 'that traditional teacher role of helping them to understand it and put it in… context, is back' (FC). Another said:

> I'm there… answering questions that they might have and trying to point them into the right direction rather than teaching from the front… it gives you the opportunity to go around and talk to every student individually and just show an interest in what they're doing… certainly with a lower school class where you've got 28 students, you wouldn't have [that] opportunity… whereas with the Internet, you do – or a similar activity… (VM)

Without ICT, more directive worksheets were used, as in this Geography example:

> …then the children focus on an example, a case study on the… earthquake. It's very much teacher-given resources. Very guided, first of all, where is it? Secondly, when did it happen? Thirdly, why did it happen? Look at the plate boundaries etc. (DR)

The situation was not entirely polarised, however, and several teachers expressed a desire for a balance between teacher direction and providing opportunities for "pupil-centred" learning. This is elaborated further below.

Another aspect of the teacher's role was that of offering *technical support,* training or troubleshooting; this was explicitly mentioned by 8 teachers and observed in most of the lessons studied. The impact of the technical difficulties arising is explored under 'Classroom organisation and management'.

Linked to increased emphasis on informal interaction was more *opportunistic help seeking*; this was observed in many lessons and commented on by one English teacher whose pupils felt encouraged to initiate conversations:

> They're sometimes more reluctant to ask for help and ask questions when they're writing in a classroom, whereas if they're working in pairs and I'm walking around watching what they're doing, they quite often will

> ask something because I happen to be there, not necessarily because they have to ask me, but just as I'm there they do say "what do you think of that?" or "how do you spell this?" (AI)

She described how the increased opportunity to provide more immediate feedback and active coaching meant that pupils were also more likely to respond to suggestions, whereas they took little notice of 'a passive written statement'.

These findings reflected a general *pupil desire for more interaction* and teacher input when working with ICT (KE, VM, YL, AI). Despite being less reliant on the teacher, pupils were reportedly keen to engage with their teacher and to receive reassurance (AI report). YL told us: 'I think they really appreciate it… when you are leaning over their shoulder and pointing things out.' This was corroborated by the pupil focus group data (Deaney *et al.*, in press) and our observations. Teachers themselves emphasised the importance of their guiding and supportive role and a widely shared view was expressed that this kind of *teacher input was essential* when pupils were using ICT (YL, AI, KE, DR, VM, OL, JN), even in the context of more discussion with peers and independent working:

> A lot of the time they were free to discuss… but I was going around, of course, and feeding them ideas, asking questions and trying to move them on, which was of course, important. So my role was critical in that as well. Had I just sat there and let them get on with it... well, I wouldn't have been able to meet the aims of the lessons, certainly. Not to the same extent. The teacher role was very important. (OL)

Indeed, while working on screen reportedly generated discussion and 'more thinking', this History teacher felt that he could have probed pupils a little more to help them structure their ideas. Similarly, while using electronics simulations successfully engaged pupils, it was considered important for learning to ensure that pupils were not using it inappropriately, which 'would be quite disastrous come exam time' (KE). One Geography teacher (DR) asserted that direct teacher input was necessary, particularly for 'theory work' and building a knowledge base, before students go on to access electronic resources and carry out more independent research. His concern that 'the [pupils'] geography has suffered slightly' led to production of extra revision sheets and impromptu use of an ordinary OHP instead of ICT in one lesson.

More generally, teachers considered themselves to be *supporting student-regulated learning* – rather than obstructing it – through facilitating information finding and developing understanding, e.g. by providing opportunities for experimentation. One English teacher who saw his role as a 'guide and facilitator' described how 'independent learning' was fostered through allowing pupils to 'show off their knowledge in a way that isn't just teacher-led' (YL). Complementary to this, the emerging teacher role here is evidently one of *prompting* pupils with the aim of *encouraging them to think for themselves* and find their own solutions (KE, OT, FC, LR, KE, VM, RA, JN etc) rather than giving answers directly:

> M asked me how to do something and I didn't tell him and he said "You're the teacher, you should know" and I said "No, you have to think it through yourself". So I was facilitating their learning because I was enabling them to experiment and the package obviously helped that process. (KE)

> This was more designed as…a thinking skills lesson, where you as a teacher… are going around just probing them and giving them stimuli but not giving them answers; very rarely when I was going around would I actually say yes or no to an answer, it would just be prompting more questions hopefully. (OT)

Likewise, his project partner described her role during the lesson in terms of: introducer, summariser, confidence builder and 'interferer' . She was prompting students to think more deeply, but most of all offering them the opportunity to develop independence and learn how to search quickly and effectively – using both computer and textbook resources.

Other teachers described how they offered a limited degree of assistance for pupils encountering both conceptual and technical difficulties:

> Where they had the single pole double throw switch the wrong way round… I picked up the circuit and deleted the component part and then I put the same component the other way round, but I didn't connect it up for them,

> and said "It's easier to visualise if it's this way round. Now have a go and see if you can do that" and then I went back later to see if they'd actually done it or not. (KE)

> I encouraged them to use logic and search and try things out because that's the only way, unless we'd asked for technical help… they seemed to be perfectly capable of trying things out for themselves and so they were experimenting with various programmes to see which one of them would set the scanner going and they found it. (RA)

Somewhat in contrast to the expressed need for teacher support and mediation, the notion that *ICT could constitute a primary resource*, reducing the need for teacher input and detailed feedback, was held by a few individuals. One Geography teacher described how he guided students through the textbook, photographs and diagrams in the classroom, and added:

> With the non-ICT I'm far more a resource to the kids. My knowledge and my means of explanation have far more impact than in ICT. In ICT they know they can get the knowledge and fulfil their requirements from the World Wide Web. (FC)

A D&T teacher asserted that circuit diagrams on paper are static and give no feedback whereas using ICT enables pupils to visualise what happens if components are connected wrongly and they can learn from their mistakes. Using ICT releases the teacher from having to go around saying, "That's not going to work":

> And they can't so easily see why that's not going to work and why that is going to work – so I think it enables them to visualise what happens; it enables them to make mistakes and learn from it. It motivates them to do the work and it helps them to produce intelligent and well-presented notes. (KE)

This teacher pointed out that directing pupils towards software 'help' facilities reduced the need for pupils to wait for technical support from the teacher (although our observations indicated that pupils were actually unwilling to use electronic 'help' and they waited for teacher assistance):

> It means that if they're stuck, they're not waiting with their hand up… they can help themselves, they can move on at their own pace… It doesn't mean they can't ask for my help, it does mean they've got more chance of moving forward without needing it. (KE)

Using ICT was also considered to provide a prop in terms of the teacher's subject expertise. In this case it assisted someone with relatively little knowledge of electronics in teaching the theory successfully, especially to more able students and where the textbook information on the topic was inaccessible:

> The tutorial activity…is actually enabling them to learn at a higher rate than they could if it was just down to me to teach them, because it's not something I'm a great expert on. (KE)

Another (Science) teacher described how structuring ICT-supported activities can free the teacher for more individual interaction with pupils; "the ICT itself does the teaching if you've got it structured correctly" (OT). In practice, this proved unrealistic, however; in his lesson involving research into solar system models, a lack of teacher direction, supervision and task focus meant that pupils floundered, failing to access and process information appropriately. The teacher acknowledged that:

> Task 2 needs more emphasis and at the same time needs a little bit more clarification… I think it was just too open-ended, "investigate further than the early models". It just needs to be more specific and more prescriptive […] My initial intention had been… [to] go round and talk to the groups to make sure that they are clear about what it was they are researching… but obviously inevitably there are groups that get left until last and they're floundering a bit more, so there needs to be… more detail at that section. (OT)

Our observations indicated that more guidance might actually have benefited the pupils in both this case and that of the D&T tutorial activity.

One project offered an opportunity for us to observe a single teacher working with and without ICT with the same pupil group. LL was a librarian teaching an optional GCSE Classics course

to a high ability group of 16 pupils; the two lessons we observed respectively involved library-based and Internet-based research on students' chosen coursework topics related to Roman life. This teacher described her role when using ICT as "bombing about", which actually involved assessing and discussing the value of pupils' chosen websites and discussing topic titles, guiding students towards generating a specific question. There was much less social interaction between the students as they worked on different topics at individual terminals; despite having had little training in electronic search strategies, they worked more efficiently, finding and extracting more facts. The teacher felt that using ICT in this way meant having students working on task, facilitating her role of checking and discussing coursework. More teacher-initiated questioning and guidance was indeed observed in the ICT-based lesson, whereas more opportunistic help seeking and offering of suggestions by pupils was seen in the library context.

The ***role of the pupils*** in ICT-supported lessons maintained some aspects of their typical role in non-ICT lessons (e.g. responding to the teacher during class discussion, soliciting and responding to help and feedback, discussion with peers, individual work) but two significant changes were apparent. First, linked to less teacher direction and greater involvement and interaction was the theme of *self-regulation,* comprising the interlinked themes of *pupil control, choice, independence* and *'active learning'* (often through hands-on experience: YL, KE, JN). These themes were critical components of several teachers' practical theories about how using ICT can enhance learning and motivation through the opportunities it provides for self-paced, active learning (Deaney & Ruthven, in preparation). The ensuing cultural change was summarised as follows:

> The fact that there was little adult intervention and that the options were theirs [freedom to choose their methods of working] and they could take the lead meant that they could be discoverers rather than followers. (RA)

> Traditionally this would have been a chalk and talk lesson… it would be… students making notes. This particular activity… enables the students to be… active learner[s] rather than passive, they are doing the job themselves, they can find as much information as they like or as little... (OT)

The increase in pupil control and responsibility (AY, FC) was linked to greater independence and was valued by teachers (such as AI, DD, YL, RE, VM), particularly where students were confident enough to select their own resources and utilise ICT to develop their own ideas, as in this English example:

> Although I gave them a rough idea of what we were going to do, I didn't tell them to do Internet research, but immediately some of them did, and some of them went off and got CD-ROMs and started playing around…That's my ideal for teaching, that you give them a spark of an idea, something to research and then they go off and get stuck in. Felt confident using the computers and the software to learn for themselves, to find out for themselves the issues of formatting and purpose. (YL)

This excerpt illustrates that while using ICT was considered to free pupils to explore by themselves (also DD, OT, RA), the confidence to do this develops over time as ICT skills increase (DD, YL, KE). Pupils' extensive – and often superior (AY, YL) – ICT skills, mentioned by most teachers, and the propensity to share their expertise with peers (evident from previous research, e.g. Schofield, 1995), were generally believed to facilitate the increase in pupil control and responsibility.

The role of the teacher in *supporting student-regulated learning* was introduced above. However, we found that the term 'independent learning' was commonly but inconsistently used in the interviews and its implications for pedagogy were thus sometimes unclear. Within the context of the increased level of individual or small group teacher–pupil interaction reported, independence from the teacher (but not peers) was implied and one teacher described

this as pupils not 'relying on whether the adults were present to move them on' (DD). While this independence was apparently motivating and most teachers mentioned that more pupils were 'on task' when using ICT, in many cases it was the more able students who 'achieved well with little teacher input' (FC) and self-directed work could make it harder to keep a low ability group on task (KE). The emphasis in teacher accounts shifted between pupil control and technical proficiency, and freeing up the teacher ('there were very few people who I really had to tutor in going through the tasks': DD). However the notion of 'independent learning' is misleading since as we saw earlier, increased pupil self-regulation can actually strengthen the need for active teacher input. Indeed, in most cases it was the same teachers who reported taking a facilitating role yet less pupil reliance on teacher intervention (YL, FC, RA, KE). Interpreting the findings as a whole seems to point to the conclusion that it was easier in ICT-supported lessons for most pupils to work without constant direction and intervention but that the teacher's support and facilitation of learning remained of paramount importance, particularly for lower achieving pupils.

Conflict was apparent in a few cases, though. One teacher expressed clear support for student-centred learning and the ways in which it allows the teacher to focus on and interact with the children more. He told us: "I kind of like the idea of the kids doing all the work and me going round", and offered some examples of pupils effectively finding their own resources through independent research (DR). The lesson we observed, however, was highly teacher-directed and interactions with individual pupils were dominated by teacher views, a desire to impart specific geographical knowledge and placing pressure on pupils to complete the tasks ("I was hounding them to get it done"). Despite claiming to prioritise pupil reasoning ("I wanted them to say *why* they're raising the riverbanks and *why* they're deepening the channel…"), this teacher controlled pupils' computers himself when providing guidance and solicited little pupil input. Hence some unexploited learning opportunities were observed. Another English teacher (RE) had carefully planned a lesson to support effective 'independent learning', but this was highly structured through clear on-line instructions and his role occasionally involved simply observing pupils. His project partner's lesson also portrayed greater teacher direction than was typically observed, and closer monitoring of pupil progress (LR). In these cases, pupil control was limited in practice despite an 'independent learning' setup.

More typically, pupils were said to be offered opportunities to work, explore or find information for themselves and were able to *work at their own pace;* four teachers (YL, OL, KE, RE) discussed this in interview and it was evident to some extent in almost all of the lessons observed. At the other extreme to the above examples, however, was the Science lesson described earlier where pupils floundered due to lack of direction and support. The teacher (OT) described how he ultimately remedied this by giving very focussed tasks to those who needed it; he realised that 'your worksheet… needs to be structured to some extent, it can't be too open-ended' and that productive outcomes are otherwise the exception. Similarly, in an English lesson (AI), some pupils were uncertain what the demands of the open-ended task were and perhaps needed more help than the time available allowed. Pupils became demotivated in both cases, which highlighted the need for a carefully structured framework within which pupils may then progress at their own pace; the importance of restructuring activities when incorporating use of ICT is elaborated below.

As with other forms of self-regulation, offering pupils a degree of *choice* within their task or working environment was considered motivating and desirable (LL, AY, FC, RA, VM, OL). For example, one History teacher proposed to create a navigational tool for pupils to choose their own path through the Intranet because 'not all kids need to start at the same place' (AY). Several teachers offered choice in the method of presentation and between electronic or other resources – typically a choice between using the Internet or books for research – thus *catering for individual preferences* and capabilities (LL, RA, VM, OL), e.g. 'some students naturally

write by hand while others naturally type' (LL). VM allowed pupils to choose the writing tool that was most 'useful for their learning' and revision (particularly if this was not available at home); in an English lesson, some pupils chose to cut and paste with paper and scissors (RA). Free choice of a wide range of technologies (word processing, Internet, CD-ROMs, digital camera) was successfully exploited in diverse ways by students in YL's lesson. However, the two examples above of pupils floundering illustrated how too much choice or open-endedness can be confusing for certain pupils, who were perceived by teachers to need more structure and direction. Free choice of Internet sites was not endorsed in some cases because 'the most exciting looking sites are not necessarily… going to help you with your work' (DD) and finding over-complex information can present an obstacle (e.g. FC). The implications of these views for pedagogy are explored further below.

The second key change in the pupil's role was towards that of *collaborative learner.* Although it is not unusual to use collaboration in some subjects such as English and Science when working without ICT, the typical secondary school working style is predominantly individual in nature. It was therefore surprising to find all or the majority of pupils engaged in genuinely collaborative activity in 10/17 ICT-supported lessons we observed (spanning all subjects involved except Design and Technology and Classics). These pupils worked together in pairs on purposefully designed tasks at a single computer towards joint outcomes; they were observed to be discussing and checking suggestions with each other (e.g. AI). In six further lessons pupils worked individually (and at their own machines), although they often discussed the tasks or shared technical expertise with each other; in the final lesson there was a mixture of collaborative and individual work. Self-selected pairs were common although some were strategically formulated using levels of ICT expertise (typically by pairing more and less competent/confident pupils, or allowing weaker pupils to work together regardless of the number of machines available: DD, FC, KE, RE, OL) or behaviour (DD, AY, FC). Some teachers used different kinds of pairings on different occasions (DD, VM, OL).

Teacher accounts indicated that more peer interaction was evident in ICT-supported than in other lessons, and they referred to subject learning rather than simply to sharing of technical expertise:

> There's been a lot more discussion generated perhaps than there might be in the classroom and I think discussion does bring increased understanding and improved learning. (AY)

In total, five teachers volunteered the information that working together was a feature of ICT-supported lessons only (and another stated instead that pupils 'prefer to work together in the classroom too': FC. In other cases, the arrangements remain unknown). Although three of these teachers remarked that pupil and computer numbers meant that pairwork was necessary, the majority of teachers mentioning collaborative working nevertheless described significant educational and logistical benefits: in particular, stimulation for generating and exploring ideas, and physical ease in terms of visibility of joint work (see Deaney & Ruthven, in preparation for details.) One English teacher considered collaboration inappropriate in the classroom: 'I think handwriting is a bit more personal' (AI).

As mentioned earlier, and consistent with our introductory discussion of research into collaboration, the *role of the teacher in deliberately facilitating collaboration* at machines – developing a culture of sharing ideas (AI, LR, VM, OT) – emerged as critical:

> I saw myself as well as somebody who is trying to bring people together within the group so they are not just sitting, staring at a screen and working independently. (VM)

> I was kind of giving ideas, sharing, saying "Can you go and look at so and so's screen and look to see what's happening over there." (LR)

Although pupils worked on individual tasks in the three Design and Technology lessons observed, both teachers involved consciously encouraged peer tutoring; for 'dimensioning' drawings (JN) and for constructing simulated circuits:

> If someone's got a working circuit… and somebody else's isn't then they're usually quite keen to come across and say, "Look you do this"… Which I'm all for. I think the best way to understand something is to explain it to someone else. (KE)

Peer collaboration or tutoring could alleviate the teaching burden ('it takes the load of questions and queries off me': JN) but as with the 'independent learning' which it supported, this did not remove the need for teachers to facilitate, to 'clarify what they were supposed to be doing' (LR), to question pupils and 'move them on' (OL). Orchestrating pair composition and mediating the peer interaction were also part of the teacher's role, for example ensuring that sufficient technical expertise was present in each group (DD, RE) and building up a culture of democracy so that 'there wasn't much evidence of free riders… sitting back and letting the other person do the work' (OL). In particular, bigger groups than pairs were said to require negotiating fair distribution of tasks and developing teamwork skills (OT).

Of course, collaborative use of ICT was not the main focus of the investigation and the data pertaining to this are inevitably limited. Thus the findings raise further questions for research since pedagogic practice in this arena is still developing and further investigation of the teacher's role in fostering and supporting pupil collaboration using ICT would be beneficial.

Collectively, these findings are closely in tune with those of the American studies mentioned earlier, despite their very different classroom contexts. They endorse to some extent the association of using technology with a culture of more 'student–centred' learning (Hadley & Sheingold, 1993) and serve to elaborate in some detail on how that culture is currently evolving in English secondary classrooms. They also corroborate the assertion of Newton and Rogers (2001, p.37) in their treatise of teaching Science with ICT that the teacher's roles of facilitator, enabler, challenger, adviser and respondent can take on more importance while the role of knowledge provider diminishes. Pupils simultaneously take on new roles involving more active and autonomous learning and peer collaboration (McGhee & Kozma, 2001). Most significantly, teachers using technology develop effective strategies for supporting and guiding rather than directing learning, and some *further mediating strategies* of this kind are now explored.

The higher level of individual teacher-pupil interaction and lower level of information dispensing associated with using ICT were indicative of a decrease in didactic *whole class teaching,* but teachers were less certain about the role of whole class interactive teaching. One History teacher told us that 'when you're teaching with computers… you tend to spend less time talking' (in order to maximise its use) but he was 'not sure whether that's right' (AY). The observer of his lesson felt that more time spent collectively probing in depth the underlying reasons (for a battle victory) could in fact have been useful. Efficiency and avoiding repetition were also an issue. JN realised that class teaching is more efficient for imparting technical skills; repeated demonstrations and interactions (task clarification, prompting and direct theory teaching) with pairs in a Geography lesson could similarly be construed as inefficient (DR). The findings also illustrated the importance of selecting approaches appropriately to meet specific learning aims, and in particular, the power of exploring complex issues within a larger group discussion rather than through individual encounters. This was made explicit in one English report (LR/RE): whilst using ICT assisted the initial deconstruction of text, wider

classroom discussion was considered to have promoted students' deeper understanding of language and meaning, and to be "an essential adjunct to work in the lab".

Eight teachers were observed to employ whole class question-and-answer sessions to assess understanding and enable sharing of ideas. Initial class discussion sessions were especially valued by several teachers who used them for these purposes and for establishing a clear focus (e.g. OL who employed an interactive whiteboard). Others (such as AY, LR, RE, OT) felt that their lessons would have benefited from additional discussion. The research team and subject specialists identified some further unexploited opportunities (for example, FC might have used an initial plenary session to structure the task more effectively and OT could have used class discussion to clarify the tasks and explain group roles for the presentation, or to discuss the notion of evidence, an important learning objective). These findings point to the conclusion that the role of whole class interactive teaching is currently under-developed in the context of ICT use. (This is corroborated by Rogers' (in press) assertion that whole class teaching with ICT tends to use the computer as a demonstration tool and fails to exploit the interactive potential of software.) Further thinking and development of this approach may help to illuminate the teacher's role in shaping classroom discourse in this context, thereby facilitating communication of the particular ideas and strategies valued by the teacher (Cobb *et al.*, 1991).

One direction which this might take is further use of *modelling,* already established as an effective strategy in many subjects. Like other forms of whole class teaching, it was hindered by the limited computer projection facilities available at the time of the study, when only two teachers explicitly acknowledged its utility. One English teacher (AI) planned to use computer projection to facilitate sustained whole class discussion of writing and redrafting, modelling the process for pupils and thereby raising confidence and security. In the meantime, she was observed to employ the techniques of (a) asking individuals to read their work aloud to the class by way of illustration and (b) reading it aloud herself to pairs, correcting pupils' work and developing poor writing structure, i.e. "modelling what I would do if I was writing that piece". Some pupils were observed to pick up this technique and read to each other. Another (Geography) teacher wanted to use a data projector for drawing attention to information on Internet sites and for modelling map and graph plotting in order to develop those skills. These examples are outlined here because access to interactive forms of projection technology is rapidly increasing, offering the potential to greatly facilitate such forms of modelling (and active pupil participation in restructuring and redrafting). Another teacher used an interactive whiteboard for demonstration and increasing pupils' awareness of others' research and analysis strategies in History; "sometimes stopping the class and saying 'look this is what [Mandy's] been doing'… can influence others" (OL).

An important strategy described by about half of the teachers was that of *focusing on subject content.* The term 'focusing' is used by Wood (1994) to denote a form of scaffolding to support learning through which the teacher draws attention to critical features of a task which might not yet be understood; it places the onus on the pupil to question and make conjectures, and to take responsibility for identifying strategies and making decisions. In our context of ICT use, it was particularly important since superficial or unthinking use of software features and overemphasis on presentation can mask underlying learning goals or disguise deficiencies in work produced and deliberate strategies are needed to help pupils avoid overly mechanical uses of ICT which can obstruct the process of learning (Hennessy *et al.*, submitted). Our first form of 'focusing on subject content' describes how teachers positively exploited certain sophisticated features of ICT in order to render certain concepts and processes more salient, for example through CREATIVE manipulation – or isolation – of text or graphic images.

Two teachers used forms of electronic annotation for explanation or reminding pupils of previous class discussion. These included adding electronic footnotes to a poem for pupils to explore (RE) and using electronic translation or annotation in order to explain difficult words and encourage pupils to use these more confidently and work more independently:

> Put the mouse over, the translation or annotation comes up, 'oh yeah, 'damnation', that would fit in really well,' without me having to be there because… they needed that kind of back-up, that support. (AI)

Text from a Shakespeare speech was deconstructed and manipulated in one lesson through creating a paragraph of alphabetically ordered component words out of context; this allowed pupils to understand key themes through looking at repetition or alliteration (AI). Using ICT was also considered to enable greater and quicker manipulation of text and formatting by students themselves than written methods can, thereby emphasising themes instantaneously and effectively: '...playing around with it, the layout of it, and the highlighting of the text and making the words bigger and bolder and so on' (AI). Similarly, another teacher successfully focused on key poetic themes by requiring pupils to segment the text into blocks of coloured font and to justify their decisions: 'once they'd thought about it, it sort of unfolded in their minds and they were able to express that unfolding, if you like, on the screen' (RE). The technology thus became a medium through which pupils could 'reflect that understanding'.

Exploiting the ability to manipulate and enlarge pictures in a History project enabled pupils to home in on their details, and providing opportunities to look at pictures independently of text meant that pupils' ideas were not influenced by reading about the picture first:

> …they weren't looking for the answer in the text, they were actually thinking for themselves first and that was something they wouldn't have done probably otherwise. It would have been more tempting to maybe look at the text first or… alongside the picture, but the way it was laid out on the screen, kind of obviated against that. (OL)

Subsequently offering diverse presentation options reportedly stimulated pupils to think more carefully about effective placement of text and image.

A second form of focusing was teachers' deliberate employment of strategies to avoid pupils' distraction by exploring software facilities or their fixation on presentation or word processing features – particularly in English. Keeping pupils on task and avoiding playing around was important (e.g. KE) but teachers' strategies involved more than this. One teacher used both whole class discussion and prompting of individuals to successfully stimulate pupils' thinking about key issues concerning format and presentation mode in the context of using a wide range of ICT resources:

> They started to think about IT not just in terms of word processing which is always the issue with English teaching – that they always just want to beautify the work and get away from pen and ink – but they actually started to get to grips with the idea of format… they are [developing] an increased awareness of how they tailor language and bend it around issues of, first of all audience and purpose, but particularly for this project, around ICT and the format in which language appears and is encountered. (YL)

Another English teacher described how experimenting with different colours, styles and fonts could lead to 'a complete mess… where by the end it just becomes meaningless' (RE); clipart was also considered a distraction. To prevent students 'just go[ing] off in any direction they can, whatever they feel like,' 'very focussed, very controlled and specific instructions' were considered essential (RE). A third teacher described how using ICT alleviates the constraints of writing in some ways so that activity was purposefully concentrated at the end of the lesson after time had been spent in thought and discussion:

> Kids don't like crossing things out, but they don't mind deleting things… on the screen there's an infinite amount of space and I didn't want [them] to fill the box up with a load of rubbish… So yes, there was quite a lot of sitting, looking, thinking and talking… and then it was almost a mad rush to get things down. (AI)

Limiting output and emphasising analysis was also a strategy employed in History:

> I didn't make a big issue of the fact that they had to type thousands of words, it was really more the discussion and the thought which went into it and them being selective about what they typed. (OL)

It is clear that in both forms of focusing the aim was to encourage pupil reflection, analysis and understanding, and that teachers perceived their strategies as successful in this way. (Some further focusing strategies specifically related to pupils finding and processing electronic information are elaborated later on.)

Wood (1994) contrasted focusing with 'funnelling' where the teacher selects strategies for pupils and controls the decision process; this is similar to our key theme ***structuring of activity,*** which also encompasses *constraining tasks*. The vast majority of structuring is *pre-planned* by teachers in their role of instructional designer. They learn from experience over time and typically trial new techniques in order to pre-empt problems; this is perhaps even more important when using new technology which, along with students' responses, can be unpredictable. One teacher described how trying out by himself the process of cutting and pasting graphic images from one piece of software to another had been important:

> …so I wasn't surprised when some of them got up quite a poor map onto their Paint document and as a result, [I] knew what to do quite quickly. (DR)

As elaborated above, exploitation of software features such as the prior annotation of texts (by AI and RE) constituted a further form of advance structuring. Another English teacher (LR) perceived a need for more advance preparation time for her poetry analysis activity. For AI, prior pupil preparation (preparatory writing and discussion, using notetaking) reportedly made the lesson much more successful than it would have been.

The perceived unreliability of ICT meant that "you've always got to have something up your sleeve, something as a *back-up*, in case everything goes totally wrong" (VM); this referred to either technical problems (mainly) or failing to cover the prescribed material or obtain enough information (OT). Back-up plans and resources included the use of Encarta (or books if necessary: DD), a resource sheet or books (DR), and chalk and talk for two teachers working together (VM, OT). Again, back-up plans seem to be more important when using ICT than other resources.

> I didn't do that at the start, but I soon learnt, of course. It doesn't take long for the system to crash and you're stuck for a lesson, you don't know what to do... (DR)

Our interviewees described how advance preparation was especially critical for Internet research, where setting *clear parameters for electronic information searches* and *pre-selecting websites* helped pupils to obtain useful, accessible, focused and relevant information (DR, FC, AY). While the Internet offers more up-to-date and wide ranging information, freedom and excitement for students, the information they obtain from 'surfing' was also described by teachers (e.g. DR, LL, AY, FC, OT) as generally less focused, less age-appropriate and ability-specific, and less reliable and unpredictable than that from other sources, which is often carefully pre-filtered:

> They've got to be much more critical and discerning in their use of sites than they are with the book stock... we buy from reputable publishers, authors whose work we know already and we had to check to make sure it's suitable for their level. (LL)

Some educational websites by contrast are university level – the language is dense and incomprehensible to school children; the format of text may also make it difficult to read and pictorial information may be lacking (DD, LL, DR, AY). One report summarised the implications of this for teachers by recommending setting of "focused, interpretative tasks based on secure knowledge of the potential of pre-selected sites" (LL). Other teachers similarly

felt that filtering information beforehand was essential, albeit time consuming (AY). DR pointed out that increasingly available lists of subject-specific sites offered little more than searching himself: "you've still got to go through them and pick out what's good and what's bad". OT described how he sifted through numerous sites to find four or five containing relevant and easily extractable information; this had the dual advantages of "focussing them onto specific points and yet at the end gives them the opportunity to look elsewhere to do their own searches beyond those sites if they feel competent enough." Personal authenticity was another criterion for success and some teachers made an effort to locate sites describing experiences or phenomena which pupils could relate to:

> What they really love are little travel logs when… they've got holiday snaps and sort of little bits of diary and they love those because there's a very, very human level. (DD)

One English teacher (RE) reported successful use of pre-selected Web links to remind his pupils of the story under study and to encourage them to explore it further and find out what happened next. He also exploited the teacher control which using ICT allows over pupil access to support materials or help; he built in password access to supplementary Web-based material so as to restrict help to pupils who had already 'tried hard enough' to restructure their poems.

There is clearly a potential tension between offering students the opportunity to explore and to find and interpret information for themselves, and directing their activity in this arena. Directed activity, especially using pre-selected sites (and Encarta), is considered more constraining and less motivating by some, however. (For example, DD's creation of a "portal" page including selected Internet links was used successfully by his group of low ability pupils but several felt that they were not challenged by this high level of support; simply typing in the URL of the site for themselves served to increase their feeling of control: DDR). Pre-selection can stifle individual expression ("kids have to have their own stamp on it": OT) and reduce opportunities for pupils to develop skill in – and a discriminating approach to – information retrieval for themselves (DR, DD). Some teachers consequently offered pupils more freedom to access and select their own material within topic guidelines (e.g. DD). One Geography teacher considered that forcing all students to access the same website can undermine the student-centred learning approach: "And then they just type it up instead of writing. So it's defeating the object..." (DR). (Ironically, as we saw earlier, this teacher's solution was to employ more 'chalk-and-talk', at least initially.) A generally held belief in pupil control meant that some teachers held back from intervening and offering too much help (e.g. VM/OT).

Teachers have developed a diverse range of *mediating strategies* explicitly aimed at achieving a *balance between reducing the degree of learner control and over-structuring of tasks* and worksheets. For example, FC interpreted the complex vocabulary and information his pupils obtained or diverted them away from highly advanced level sites if necessary. One Science teacher condoned independent open-ended searching but since this did not always prove fruitful, he imposed a 2-minute time limit on pupils before intervening (OT). Semi-structured tasks of all kinds were also popular ("it wasn't too dictatorial for them and it wasn't too open": AI; OT) and varying the degree of direction for different research tasks was also described (RD). OL balanced a degree of direction and focus in research with allowing pupils freedom in how they subsequently communicated their ideas. Another solution constituted an alternative to providing addresses of appropriate sites by incorporating these into an Intranet – thereby providing a bounded database of accessible information which pupils can then search. One pair (OL & AY) found that prior creation of a History Intranet helped to eliminate the problems associated with more open-ended Internet use (although it was very time consuming); it offered faster access to manageable amounts of more reliable, pre-selected information and avoided the potentially 'disastrous' lack of outcomes from open-ended Internet searching (cf.

Harrison, in press). DR similarly reported that pupils successfully accessed appropriate information from the Geography page created on his school website. Another solution was the strategy of gradually withdrawing support from pupils (FC, AI, JN, VM, KE):

> I want to get back to the stage where there's less simplification, less spoon-feeding from myself in terms of websites and searches so eventually I'll discard simplification just to pull them forward. (FC)

One English teacher reflected on his attempts to balance between being over-directive (providing more security but limiting imagination and risking similar task outcomes) and under-directive (providing opportunity for independent learning but risking confusion about task requirements). He found that different degrees of structure proved appropriate for different pupils: "the kind of looseness and the vagueness of the lesson I think, helped some, but for others I think they were lost" (YL). Several others found that lower ability students benefited from more specific procedural guidance and less open tasks (AY, LL, OT, JN). One Science teacher (OT) provided pre-selected sites for pupils to use in preparing for class discussion, but the questions were very open-ended, as was the subsequent research task, where sources were left up to pupils. The teacher reported that he had intended to rely on circulating among groups to "make sure that they are clear about what it was they are researching" but that some groups were inevitably delayed in making a start through lack of direction from the teacher or the worksheet. This teacher was also reluctant to lead pupils when approached directly for help. Consequently, as we saw earlier, many pupils floundered during this lesson and the teacher realised that clearer and more detailed objectives were needed for some – described as students with 'an attention problem' (actually all pupils might have benefited from more support in this lesson).

While most structuring has to be done in advance of a lesson, some forms of *structuring in action* were also described. One teacher reported helping students find information by imparting a Web address initially and adding further appropriate sites during the lesson as needed, as children themselves locate them (FC). Another wanted to differentiate the activity by ability as the need arose by distributing progressively more challenging tasks (DD). Pacing children's progress with an activity (elaborated later on) was a further strategy and the most visible one observed during the lessons (e.g. LR).

New pupil skills – and the teacher's role in fostering these

One of the most important skills which pupils need when using ICT is that of *finding information*, particularly *techniques for searching the Internet,* where selection of appropriate sites is dependent on an understanding of how to formulate keywords. Two teacher-researchers (LL, VM) asserted that such search skills were generally useful and particularly for higher education. One of these (LL) was a librarian whose project focussed on information retrieval (for Classics GCSE coursework). Her experience of assisting pupils to carry out searches for information in a variety of subjects served to highlight the importance of teaching students to define appropriate search terms and to refine them, even before using a computer. Her report indicated that this made information retrieval more efficient (although pupils were apparently less convinced and 'resented teacher intrusion' into their domain of 'expertise and power'). LL criticised other subject teachers for not giving students enough guidance:

> My impression is that they don't get much on actual search technique. It's just 'Look up X.' They don't actually think about what you put in.

In her own lesson using ICT, this teacher found that some students floundered a bit: "she couldn't find anything on Crime and Punishment, but she hadn't thought of her search tools" and the teacher's own lack of familiarity with some websites was problematic too. In some cases too much information was obtained: '…more isn't necessarily better, is it? More is just

more confusing.' She regretted not thinking through keywords with students beforehand and planned to spend more time on teaching search techniques in future. Her report confirmed that later lessons required 'thinking about the information retrieval process and devising lists of search terms before searching the Web'. However she noted that pupils' searching was more direct and efficient than it had been in the previous library book-based lesson on the same topic. Not only did pupils prefer using ICT to book sources ("their natural first port of call is the Internet because that's what they do at home, that's what they do here...") but in the library some students were still searching after 5 minutes, wandering uncertainly around (information on some topics was not all grouped together), 'whereas with the Internet they knew exactly and they just put in the key word and found things out'.

Another teacher described how pupils developed confidence in searching, copying and pasting during the project whereas initially they had been continually seeking help or reassurance (DD). At the same time the open-endedness of Internet surfing increased pupil motivation:

> ...specially some of the boys… for them, the Internet is fishing because you cast and you don't know what you are going to pull back and… they get the same sort of excitement about getting a really good result as pulling in a nice fat fish. With Encarta, it's a bit like buying fish in a shop because it's all set out… they quite enjoy the unknown.

While some teachers felt that pupils locating their own sites helped to develop their search skills, the inaccessible information sometimes obtained meant that teacher pre-selection of sites was necessary (FC, OT), as we saw above. Others maintained, like LL, that *developing pupils' own search skills* was the way forward. One Science teacher set semi-structured Internet searching tasks to encourage the development of independent searching and selection skills outside of lessons (VM). Another teacher found that providing or negotiating keywords and hyperlinks proved to be the most useful strategies in keeping pupils focussed (DDR). He pointed out that whilst provision of keywords made for efficient searching, pupils still needed to be able to select suitable sites from the list of search results. Once a site had been found, two further strategies proved effective in avoiding pupils' distraction and frustration caused by extraneous information, advertising banners, and a complex range of optional links: helping pupils to focus on the search for key words on the page, and improving legibility of difficult sections of text by cutting and pasting it onto a plain background, then manipulating it using word processing software (DDR).

The other set of skills that pupils need to develop concern the *processing of information* derived from the Internet and similar sources; its potential complexity and unreliability mean that simply accessing the information 'out there' is insufficient. Teachers thus need to *develop pupil skills for forming their own ideas, for interpretation and critical analysis*. Curriculum pressures in some subjects like Science may hinder this. For example, in one Science lesson, the children accessed information pertaining to scientific models and were then left to analyse and defend these by themselves; their lack of skill in critical analysis and scientific reasoning was observed to hinder their progress (OT). The teacher recognised the deficiencies of Internet-derived information and the importance of developing these pupil skills but expected that providing clearer task objectives on the worksheet would suffice.

His project partner similarly recognised the need for pupils to develop 'the ability to extract useful and relevant information', again for future use:

> When they go on to university and things like that.. I want them to be able to work independently, ultimately to search independently on computers through texts, realise that the computer isn't the only… source of information. (VM)

Yet pupils were expected to develop their skills through 'semi-structured' homework tasks; these pupils were in Year 12, the oldest in our study, and may have been expected to work more independently than younger pupils. Pupil independence was certainly valued:

> It allows them the freedom to sit and search for themselves and to get through useless sites and to really find good bits of information… I don't feel as if I'm really needed as a teacher in the room at the time doing that.

A clampdown on indiscriminate printing (via instigating a termly page limit per pupil) in this particular school meant that little printing was observed. In OT's lesson, pupils were reported to be successfully cutting and pasting into WORD 'key chunks of information so they can sift through that at a later date', in this case in order to prepare a group presentation to the class.

> That was quite an achievement… they are actually processing some of their information before they start pressing the Print button. And they are being a little bit more choosy about what information they can try and extract. (OT)

This teacher believed that using the Internet for research was more time consuming but actually provoked more processing of information – and thus learning – than a 'chalk and talk' lesson, where

> they would have had a set of notes, but there would have been very little processing. The chances of them looking at those notes again were probably miniscule. (OT)

Nevertheless evidence that merely by selecting, copying and pasting information into their own documents, pupils could understand and analyse information critically was generally not very strong:

> Some of them adopt a strategy of cutting extended writing from the screen, pasting it onto their Word document and then going into that and changing it into their own words... they must then be actively reading that sentence or that paragraph and actually understand it to be able to change it, so I don't mind that. (FC)

Indeed this teacher's project partner (DR) perceived that pupils struggle with critical analysis and lack the ability to focus on relevant information:

> They'll read a whole load of information on the Internet and… not particularly get a lot back, whereas the control group… all the stuff they read is focused on what they will do for an exam… For instance, this is a waterfall, let's have a look how it's formed. Whereas the IT group are having to read through a whole load of information on waterfalls and try and pick out. So maybe they've developed new skills about reading and analysing information, but I think that's perhaps a little bit beyond 12-, 13-year-olds.

His solution was to filter the sources that pupils can use. AY agreed that pupils can get bogged down in the volume of information obtained. In his lesson they were expected to highlight or paste (reasons for a battle victory) but this was thought to be easier for some individuals than others. Similarly, FC found that although pupils search skills had improved greatly, expecting pupils to find appropriate Websites without much teacher input proved unrealistic.

An interesting school effect emerged here. While some teachers (e.g. DR, OT) perceived teaching in terms of delivery of an objective set of knowledge, the culture at one particular school (CC) fostered a view more consistent with knowledge construction through interaction with personal experience and frames of reference (Eisner, 1991). This was reflected in an emphasis on developing 'thinking skills' throughout the school. In the History department, where teachers in any case seem more comfortable with uncertainty than in other subjects, one teacher described how pupils are changing their perceptions of the subject and successfully developing the ability to copy and paste text selectively and reflectively:

> There's a shift now… in the way that the pupils see the subject from content and writing lots, to putting more time into thinking and being more selective. (OL)

Another teacher at the same school experienced uncertainty about how students had processed information derived from any medium, but realised that more concrete evidence was required before judging success:

> The only one I was quite sure that had processed the [Internet] information was the girl who was actually writing notes. (LL)

It was reportedly 'more difficult to ensure that pupils had internalised and reprocessed information they discovered' when a pre-selected site was accessed: 'there was a tendency to print out material indiscriminately or… e-mail key site pages to the students' home computer' (LLR). The teacher also pinpointed the dangers of students' own lack of awareness of the pertinence of material. One low ability student in her lesson

> didn't know he was struggling but I knew he was struggling because he was finding pictures, which he thought were relevant... and he found some nice maps, but he wasn't actually extracting the information. (LL)

However, in contrast to the views of teachers at other schools that analysis of electronically derived information was over-ambitious, her project actually focused on developing students' critical evaluation of Internet information through deliberate teaching and reinforcement of generic search strategies:

> The research was attempting to devise strategies to enable students to develop as independent, effective, efficient and discerning electronic information gatherers rather than remain as serendipitous and credulous surfer-browsers (LLR)

Although her students were also a little older than average (Year 10), this was a general aim for all secondary age pupils. Specific strategies employed by LL included teaching pupils to highlight key points on printouts (as AY did) and encouraging processing of information through note writing (as they were observed to do with print-based information). She also conducted class discussions aimed at getting students to think critically about the nature, source and date of information retrieved. Again, she considered this to be a generic skill also applicable to book-based work (pointing out that secondary sources can contain contradictory statements) and one which becomes more important with further education. Another teacher who specifically attempted to develop pupil skills in this area (FC) encouraged active reading and understanding of electronically derived texts through asking pupils to change texts into their own words or to formulate bullet points, rather than engaging in the extended writing typical of other lessons.

To conclude, these examples highlight the realisation by a few teachers that explicit development of pupils' information retrieval and 'critical literacy' skills is needed in order to cope with the less focused and often inappropriately pitched information that using electronic sources can yield. As has been noted previously, it appears that pupils continue to present unprocessed information (Ofsted, 2001). While pupil skills in this area are now developing, the complexity of those skills may be under-estimated and there is little evidence that pupils are learning them without support. Individual teachers have developed some useful initial strategies for supporting extraction, evaluation and presentation of summarised information, however these are by no means widespread. There is some disparity between those teachers who expect pupils to develop information skills independently or through task focusing, those who try to teach them, and those who feel they are beyond pupils' capability. Issues for consideration when pupils are researching independently include the currency, reliability, accuracy and partiality of information on Internet sites. Many teachers tackle the inherent problems through pre-selection of sites. This is considered helpful in ensuring access to suitable content pitched at an appropriate level of understanding, although it raises a tension by undermining the degree of pupil control which an Internet-based research activity can then offer.

Implicit in the above discussion of teacher and pupil strategies is the notion that the teaching and learning ***resources and tasks*** employed by teachers can contribute to the structuring of classroom activity using ICT. Indeed lesson success was commonly attributed first and foremost to carefully defined aims and *clear, focused, controlled, structured tasks and*

resource sheets in paper or electronic form (e.g. DR, LR, RE, JN). The need to keep pupils on task was one motivation**:**

> we've found with this project is that having kids focus very clearly on what we want them to do, is much better than saying 'right go off and research this or that'. That tends to sometimes lead to them being a little bit off task, particularly the kids who are probably better with their IT skills. (AY)

Other teachers designed their tasks and materials to provide effective scaffolding and staged support for less confident pupils and to help promote an independent approach to learning (LR, RE, JN)**.** We have mentioned that some teachers used the technique of gradually withdrawing support and this was sometimes embodied in the use of progressively less structured tasks. For example, JN withdrew support for the most able children: "…the sheet that I wrote started from a very full helpful hint… and then step two, for the side view, had less instructions" whereas lower ability pupils needed more step-by-step instruction.

Several teachers had clearly learned from experience, particularly during the projects they executed, that too much open-endedness in ICT-supported activity was problematic.[6] They had therefore introduced more structure, particularly into research tasks. FC identified a site in advance for the first time for the lesson we observed, and AY told us that initially

> we left too much open and... the kids felt a lack of clarity… but this task today, it was certainly well structured and they went from point to point to point and generally I think that's worked better.

Similarly, OL felt that completely open-ended tasks led to time wasting by pupils and thus constraining the task was important:

> I didn't really allow them any research. I focused on 2, or 3, 4 pictures and told them which ones – because that was important that they weren't spending too much time… (OL)

We have also seen how during the lesson observed OT learnt that his worksheet needed to offer more structure and guidance when introducing the task, providing sufficient information for students to start work straight away: "there needs to be something else that comes in at that point which points them more in a direction that we want them to look at." His report (joint with VM) concluded that

> 'Successful' integration of the Internet relies on well-planned and structured lessons, with clear objectives that enable differentiated activity; and… planning should include familiarisation with relevant material on the Web.

Teachers' experiences also highlighted some opportunities to assist pupil navigation during research activity, and some teachers had devised ways of using resources to do this. One planned to create an (update-able) navigational tool for the History Intranet site (AY). Another planned to retain the 'flexibility of the number of websites' listed on her worksheet but to provide extra direction by adding a short descriptor for each website (VM). Similarly, RA planned for pupils to create (on paper) an outline map of the site and its hyperlinks – so that they could step back from the mechanics of the process and understand 'that certain things link in [predictable] ways with a central text' (RA). It was also noted that using hyperlinks is easier for students than typing complicated URLs and providing hyperlinks within worksheets was found to have an 'inordinately beneficial' impact on lesson success since it reduces search time and time wasting through incorrect typing of web addresses (VM). Use of colour and highlighting was deemed helpful too in making links more salient (RE, SS, AI).

While using ICT evidently offered some unique features and sources of information unavailable elsewhere, teachers felt that textbooks can still play a role as a research resource. Four teachers highlighted the interchangeable or *complementary nature of electronic and other*

[6] Even where teachers proclaimed the importance of task structuring, the need for even tighter structuring and clearer criteria and focus was detected in some cases by the subject specialists who independently assessed our lesson observations and interview data (e.g. DR, AY, OT).

resources (VM, OT, LL, RE). For example, OT considered that only certain topics such as the one under study (Space) "lends itself… to the use of ICT and… the use of the Internet", and he encouraged students to find resources from different sources:

> ICT is a tool and I strongly believe it shouldn't be treated really as anything different… more than any other resource. One of the reasons for integrating the textbook work at the beginning in some small way is to emphasise the fact that the Internet isn't everything, that you can get information from books still, they aren't completely redundant. (OT)

Another teacher (VM) described Internet use as "like an on-line text book when it comes down to it":

> …just using it as a different source of information and ...helping them to develop the ability to extract useful and relevant information, rather than copying out huge chunks, which is hopefully what is happening – or, chalk and talk from the front is another way of doing it.

She relayed how most students in her lesson had not realised that they could still use textbooks to find definitions in an 'Internet lesson' and needed prompting to do this, although it was in fact much quicker for the task in hand.

Apart from text-based resources, pictorial information was deemed necessary for some activities so that teachers felt they needed to provide this on paper if it was not available electronically (LL, DR). Practical demonstration retains some importance and visual aids can also enhance learning during ICT-supported activity; for KE, "having the actual [circuit] switches to show them" was critical. The balancing and combining use of electronic and other resources was a common theme (AY, DR, KE, RE, OT, VM) and was embodied in the notion of *multisource learning*, the term proposed by the research team for a pedagogic strategy to which one subgroup of teachers initially subscribed; thereafter teachers interpreted it for themselves. This was already said to be in place in two departments (DR/FC, OL/AY) before the projects began, however all four teachers incorporated new resources so that their projects extended the range of materials and possibilities (at low cost):

> Looking at a variety of sources is nothing new to that group and it's a basic tenet of History teaching at KS3, but looking at art, painting, drawings was something which was new. (OL)

AY argued that the Intranet site created was itself multisource; it offered battle accounts, biographical information, letters, diaries, posters, pictures (the teachers also used film and a field trip to offer further dimensions). This promoted more of a 'total picture' and gave the students 'far more they can use to substantiate their arguments' (AY). The final report by OL/AY linked the notion of multisource learning to the nature of History and claimed that while it handled the same concepts, it enabled pupils to 'support their findings in a more sophisticated way by the ease of incorporating evidence into their work'. By contrast, the English and Geography projects in this subgroup did not in practice employ multiple resources during the lessons observed. One Geography teacher restricted himself to a narrow set of Internet resources while his partner aimed to work throughout the project without handout sheets and books altogether (associating these with didactic theory teaching).

Across the projects in general, despite the interview talk concerning the complementary nature of material from different sources, in the actual lessons observed there was little evidence of pupils' integration of such material or their use of ICT to combine and structure it (cf. Harrison, in press). The linking of ICT use to ongoing teaching and learning described by Finlayson *et al*. (2002) as characteristic of successful practice generally was inconsistently observed. Whereas this was clearly evident in the History project (OL/AY), for instance, use was modular in some other cases (this was perhaps a feature of activities being under trial before integration).

A significant theme emerging concerned the perception that *printouts, other text-based resources or pupil records* of ICT-supported activity were necessary for later reference (YL, AI, KE, DR, LR, RE, JN). (Again this was a lesson learned through experience on these and similar projects.) *Pupil records* – either printouts of activity or written notes/sketches were considered especially important to support learning and for subsequent revision. One English teacher perceived the use of exercise books to have been successful in his lesson, where students recorded points that were 'very focussed and very sort of pithy' (RE). For another teacher, 'having a lovely little bit of printed matter' was a desirable – yet often elusive – written outcome of the productive discussion and analysis she observed in her lesson. A third English teacher wanted to explore the notion of tracking changes in student writing and assessing it on screen, although technical difficulties meant that accessing a succession of drafts was tricky: 'unless I get them to print off or save the first draft.. when they make the changes, I can't see the changes' (AI). Regular printing could also provide feedback in Design and Technology, where for instance, students could see if their drawings were to scale (JN). In sum, printed interim records are not always considered necessary, but they are obviously useful at certain stages in some activities.

The pair of Geography teachers working together were mainly concerned about printed records in the context of revision. Here the groups predominantly using ICT were disadvantaged through minimal access to printouts or the original sites; these students could only revise at school using the computers in their own time, whereas other groups had copied information from a textbook (FC). DR pointed out that he would therefore need to create a revision booklet providing additional information, a time-consuming enterprise. Pupils' progress may be hindered because they do not always conform to teacher expectations that they will take notes or print out at appropriate times. In a Science lesson, pupils were observed to move through a succession of tasks without initially recording information which would have helped them subsequently, despite the teacher's hope that they would 'make some brief notes in their exercise books or using WORD'.

The precise reasons for the limited degree of printing observed generally in our observations remain unclear but they no doubt include technical issues and lack of access to printers, the cost deterrent (DD, AI, OT) and perhaps in a few cases, low priority is ascribed to printed records. Ironically, a technical problem resulting in a lack of printouts in one case (LL) proved useful because students could not simply submit pages of printed research output and were forced to process information obtained, through notetaking. Another teacher (AY) asserted that students using the computer like a notepad helps to develop thinking skills, whereas printed resources are costly so cannot be scribbled on, although presumably manipulation of ideas on a large sheet of paper could serve the same purpose.

Teacher-produced resources – worksheets and other handouts (including photocopied material) were also considered key to lesson success. They were employed in most lessons to structure activity and support hands-on work, and to provide a more reliable record for future reference and revision than pupils might produce for themselves. For one English teacher, the worksheet provided a reference point for judging successful outcomes; the aim was 'to make formal the link between research and the final exam' (YL). The combined provision of online and written worksheets – 'being able to write things down on the worksheet and yet working online live' – worked very well for OT (once students realised that the content was the same and they could utilise both media). KE provided a variety of sheets providing 'information to revise from – information to support their project work and so on', but he deemed it important for pupils to produce their own notes as well:

> If I just give them notes, my concern is they don't read them, they don't take on the information and internalise it… Equally, if I just get them to do the activities on the computer and don't give them notes, they can be producing erroneous information, so… they're revising from that. So I think both approaches support each other.

'Sense' and accuracy of information in pupil notes was ensured through the teacher checking them later on. This raises the thorny issue of *assessment* of ICT-supported work, since pupil notes can in theory provide a very useful means of assessing their understanding – as in the above case and that of PW, who planned to assess pupils' written homework about deforestation and desertification. However, while several teachers claimed that pupil understanding had progressed during the course of the activity, there was little evidence. Indeed some teachers expressed uncertainty about how to do this (during post-lesson interviews):

> That's a question that we've asked them and many, most probably, answered "I think I made more progress because I enjoyed using the computer", that type of answer, so… measuring in fact how effective their work has been using the ICT, is quite difficult. (LB)

Few described any concrete plans concerning how to measure ICT-supported learning; exceptions included looking at test/exam results or coursework, or trying to map work onto NC levels. One Science teacher described the difficulties with this when developing new ways of using ICT – in this case the Internet – to support teaching of a topic:

> We tried… a long time ago… to match levels to the kind of outcomes that we're going to see and we found it incredibly difficult trying to hypothesise what the students were going to produce… one of the advantages of running this early is that I'm going to have a set of work… from real kids and I'll be able to say… "this feels to me like a level 4 type of piece of work, this one feels more like a level 5" and so on… So it will be assessed but at the moment I'm not sure how… This is brand new to all of us, but then once we have got it clear it will come in for the rest of the Year 9s so it's important…it's a difficult task though. (SP)

Using ICT is perceived to offer some release from laborious and routine manual processes and this means that learning objectives may need to change. In particular, the present assessment focus on end products becomes less relevant in a context of greater speed and ease of producing them. For example, it is pointless to assess the quality of graphs or tables of data which pupils print out; the extent to which they have analysed and interpreted data appropriately becomes more apparent instead (Barton & Still, in press). The *processes* involved in practical work, writing or research activity thus become even more important. Assessment of understanding or analytic skills may now take place *during* the activity. For instance, the teacher may circulate, asking probing questions of pupils about graphs, drafts of written work or research outputs visible on their screens; we observed some probing and monitoring activity of this kind which could perhaps – in future incarnations of the activities being trialled – provide a basis for formative assessment. Interim records of activity may be useful indicators for assessment as well as for the reference/revision purposes discussed above. Instructions, tasks and means of recording activity consequently require careful planning. One History teacher asserted that "structuring the task properly" was necessary to "allow them to show what they've learnt" (LB). While the concepts involved may be similar, using multiple sources meant that "they've got far more they can use to substantiate their arguments… Probably the difference between a kid who achieves one level and achieves a higher level". However, he was still unsure whether National Curriculum levels were "the right way to measure output here?":

> We were fairly sure about that at the start because we have to live within that kind of system, don't we, but there may be other ways that we might look at to measure how effective what we've done, what the kids have done, has been.

To conclude, since using ICT is associated with a gradual shift towards new forms of pupil activity and ways of teaching, it can be argued that assessment frameworks themselves will need to change to reflect this (McFarlane, 2001). Teachers are beginning to consider their role

here but external constraints currently limit the scope for change. Finally, identifying individual contributions in collaborative work is a notoriously difficult area but the benefits of this style of working provide an incentive for making an attempt – again perhaps using discussion with pupils and observation during their activity.

One feature of task and activity design which actually increased in importance during the projects was that of *differentiation* – both by subject ability (JN, LL, DD, AY) and the added layer of pupils' technical skills and experiences (YL, RE, LL). One D&T teacher found that use of flexible electronic tutorial activities contributed to effective differentiation of tasks and outcomes whereby more able pupils could extend their knowledge whilst others continued to work on basic tasks (KE). However, it was notable that after reflecting on their experiences, 9 of the 15 teachers interviewed planned to include more differentiation in future lessons, mostly by tailoring materials to challenge and support different abilities and capabilities, and particularly by providing more direction and help with Internet research for those who needed it (LL, OT). One English teacher planned to acquaint himself better with the diversity of levels of technical skills within the class to enable a more purposeful (rather than serendipitous) differentiation of activities. Another similarly planned to compose pupil groups to take account of their existing technical skills and experiences and to pitch their work at the appropriate level. While differentiation is an important feature of lesson planning generally, it seems that it may become even more pertinent in the context of using ICT.

Classroom organisation and management

Contextual (physical, financial, organisational) factors can interact with pedagogy to shape the ways in which ICT is used (e.g. Schofield, 1995). The major influences in our study were that of the *physical environment* of technology use upon classroom interactions and management of pupil behaviour, and the relationship between *technical difficulties* and *lesson pacing.* We consider these here in turn.

The first pertinent feature of the *physical environment* was *room layout,* which was observed to have a marked impact on the ease for the teacher of viewing students' screens and circulating around the class. Using a dedicated ICT suite proved distinctly preferable in most cases, especially compared to classrooms containing computers or the library/resource area of one school (CC) where most ICT-based lessons were carried out. Placement of machines in long rows and more cramped together in such situations proved especially problematic. Teachers complained that this obstructed teacher movement and inhibited interaction and monitoring (AY, DR, OL) and our observations confirmed this:

> You can look at the screens very quickly, whereas in the library it's much more difficult having to fight your way through where the children are sitting. (OL)

Consequently:

> There's some new… strategies that I can use in that room, that I wouldn't have been able to… because you physically can't move the chairs round in the other room so easily – and that has been an issue in some lessons. (OL)

The Science lessons observed were carried out in a laboratory with 12 computers placed around the periphery on tables with a layout such that one member of each pair sharing a machine could not reach it. OT acknowledged that the onlooking partner was disadvantaged and inevitably made less progress but he expected to redress this imbalance next time by ensuring that roles were switched. He pointed out that rescheduling the class to a dedicated ICT room would have provided more machines and might have helped contain the more restless students who tended to wander around in the lab, presumably reflecting their inability to participate. The same room worked much better for VM, who only had 14 pupils.

Nevertheless these pupils worked mainly in pairs with the same restricted access for some individuals. In groupwork situations, the space between computers was considered especially important. Access to a spacious suite offered an advantage for one English teacher:

> I think the distance between the computers, how close the group is next to you is an important factor. In another room we were far too huddled together and there was far too much crossover. (RE)

Thus there is an adverse *interaction between collaboration and room layout* which is not conducive to it. This can result in unequal participation, especially by 'free riders' and more reticent pupils who allow others to dominate the computer. Strategies for sharing both the keyboarding and the input of ideas need to be implemented (AI, OL, OT).

Another key recurring theme concerning room layout was the issue of *attracting and maintaining the attention of pupils sitting at computer monitors*. Whole class teaching without using computers was considered easier from a physical point of view since all students could see the (same) board (e.g. DR). By contrast, deliberate strategies were needed to resolve the problem of computers distracting pupils during class teaching and discussion. These strategies included holding off logging on, and introducing the lesson in a classroom elsewhere:

> I'll probably start that in here and then they'll actually physically do it on the computers. Just so that I can see all their faces and know that they're not typing, reading their own instead of listening. (AI)

One Geography teacher typically briefed the students in the classroom – where he could more easily maintain authority and retain attention – before moving to the computer suite:

> It just helps my authority a little because I'm in my space and when we get across there, it's not my domain and so… it's more difficult to call them all to attention when they are not naturally people who give their attention. (DD)

However, moving rooms could be inconvenient and disruptive:

> There's no way that you can really get around that problem: of needing to speak to them, but wanting them to do it behind a monitor in a different room... I can see why a lot of teachers don't want to use IT. (AI)

One exception was the History teacher who was able to make use of an interactive whiteboard in the ICT suite used for the lesson we observed, in order to provide an effective focal point for demonstration and display of Intranet material. As mentioned above, this kind of projection technology was not widely available at the time of the study and its increasing penetration will probably help with attention holding. This teacher maintained that pupils working behind monitors continued to listen to the teacher (pupils "were just typing away and looking at the screen, but they responded well": OL). Nevertheless one English report (LR/RE) described the difficulties faced in interacting sufficiently with students in a computer laboratory; traditional whole class discussions were recommended to compensate for this and to help develop deep levels of understanding.

Lesson pacing and technical problems

The use of dedicated software and technological tools such as data logging and calculators has been reported elsewhere as offering a 'time bonus', in terms of allowing more teacher interaction with pupils (especially low achievers), more investigation, interpretation and discussion – particularly in mathematics and science (Finlayson et al., 2002, Ruthven & Hennessy, 2002). There was limited evidence for this in the contexts studied here. While views about the *pace and productivity* of lessons using ICT were conflicting, the more dominant view was that the pace was slowed down, sometimes in unanticipated ways (DR, AY, RE, RA, JN, OT). One likely factor of influence is that some teachers were trialling entirely new activities and the majority were using ICT to teach established topics in new ways, so that timing was uncertain:

> It's like being an NQT in some ways or a student teacher – you can't sometimes believe you don't get through everything in the lesson. (AY)

Many lessons were found to need rejigging because time proved to be too short. For instance, in one Science lesson, insufficient time was allowed for initial information gathering and some pupils went on to prepare their presentations prematurely:

> Inevitably there's going to be a short period of time where they are just trying to work out what they are doing, there's going to be a number of them who are more interested in opening up PowerPoint and trying to play around with fancy titles… (OT)

Consequently the pace was slower than the teacher had hoped; he expected that a short, focussed discussion would be preferable to the note-taking task next time. Delays were also attributed to an extra stage in the learning curve when using ICT:

> Non-ICT is quicker but that is because we've set it up in a different way. You can just get moving on it, whereas with the CAD you had to teach them the initial commands first before they could produce the drawing. (JN)

Similarly, DR found that using ICT was 'a chore' in some lessons, particularly for 'theory work'; without it, he guided students straight through the information but the class using ICT had to access a suitable website first. Some teachers found that slow network connections could lead to delays when using the Internet:

> Because of the time it was taking to download material I was finding it very tedious to wait for them to wait for material… there was lots of time being wasted. (RA)

For OL, creating the Intranet instead 'saved a huge amount of time'. A handful of other individuals (YL, AI, RA, KE) perceived that the pace of their ICT-supported lessons was faster and productivity was increased accordingly. Two English teachers believed that less learning would have taken place without the use of ICT:

> I think it would have taken perhaps two or three lessons without it to accomplish less than I could achieve with those computers. (YL)

AI felt that a classroom lesson would have been slower with more discussion before writing whereas looking at a document on screen meant that pupils worked quickly to generate ideas. She expressed surprise at how far the pupils progressed (including some who would not normally produce much).

Teachers employed a range of *strategies to maintain the pace* of lessons using ICT. A number pointed out that chivvying pupils along and careful monitoring of progress were needed to keep pupils on task and retain a focus on the lesson objectives (AI, KE, RE, LR, VM). We saw above that the context of using ICT placed a particular demand for employing strategies to avoid the distraction of pupils and teachers from subject teaching and learning by technical facilities and issues. In one case, serendipitous use of a Smartboard helped the teacher (OL) to monitor pupils' progress. Pre-empting time wasting due to pupils' lack of technical skill was a further concern:

> One role was as an ICT teacher, showing them a new skill, making sure that there weren't any problems with that and as a result, none of the children spent too long on that trying to mess about, trying to work out how to use Paint. (DR)

One English teacher (LR) constantly readjusted the timing of activities during her lesson. She reflected that a clear time frame would have supported paced whole class learning and that discussions with small groups of pupils could be 'very productive' but inefficient:

> they weren't really… of benefit to the whole group, although they could have been… But we really need to have that kind of time collectively… because then they would… [have] been a bit more tuned in... Instead, some of them got side-tracked... (LR)

Similarly, JN maintained that it is easier and more efficient to teach some tasks (such as printing) to the whole class together rather than to individuals.

In sum, teachers may need to adjust lesson plans and schemes of work after trialling. For instance, OT decided to extend the topic from two to three lessons after progress was slower than anticipated in the observed (first) lesson. Another English teacher was pleased with the pace and productivity and considered that pupils had tackled tasks appropriately ("they were very focussed and they listened when I said 'don't spend too long on the pictures'": RE) but planned to divide the work more realistically into two lessons next time.

Teachers may also require strategies for using the time available more optimally and tackling the confounding technical issues which can dominate – and slow the pace of – classroom activities supported by ICT (Harrison, in press). Certainly, in our study, *technical problems* proved highly problematic and although our focus is on strategies for success, the impact of technical issues was so great that it cannot be ignored. In interview, nine teachers mentioned previous negative experiences or the adverse impact on their teaching aims of a lack of available or reliable technical resources. Despite the careful planning that no doubt went into the lessons we observed, seven teachers mentioned a significant impact of technical problems or demands in their lesson and the researchers themselves observed significant problems in 10/18 ICT-based lessons studied. These included the loss of most of a lesson's work in the case of one small group and in another lesson, a complex network fault resulted in a severe impediment to using ICT and very limited pupil progress. (Both of these occurred at the highly resourced Technology College.)

Our findings indicate that existing technology infrastructures and levels of technical support cannot cope with the increasing demand upon resources; the impact of this on classroom teaching and learning must not be underestimated. (Our earlier focus group interviews with pupils confirmed that pupils were often frustrated at the amount of time they could spend waiting for teacher assistance when technical problems detained them elsewhere: (Deaney *et al.*, in press). Clearly, having to deal with technical issues often means that time is lost and lesson plans are undermined, with critical aspects sometimes having to be abandoned at the last minute. In some cases teachers felt that the *management of ICT* was taking over subject teaching to some extent (VM, AI, OT) although a couple pointed out the counterbalancing effect of less time being needed to manage behaviour owing to increased pupil engagement. Two English teachers reported that in a normal lesson involving pupils writing by hand, more active management of pupil behaviour is required (AI) since 'there's more scope for people looking around and not paying attention [while] there's something a bit more riveting about the screen' (LR). By contrast, using ICT can free the teacher from typical classroom management issues (LL). In one case, simulation software absolved the teacher from acting as a 'storekeeper' of materials:

> It makes the management of the lesson so much easier and therefore I can spend more time dealing with their enquiries and understanding. (KE)

Teachers tackled the myriad of technical problems facing them as best they could in the circumstances (of limited technical support generally). Back-up strategies and resources have already been mentioned and flexibility in responding to changing circumstances – a feature of teaching generally – was observed on several occasions when original plans had to be abandoned. *Homework* (especially further research) was sometimes used to make up time lost or to save lesson time by preparing students for the next lesson, in particular for thinking outside the lesson so that the next one could be more focused (LL, AI, LR). For example, OT

reported that enabling students to access their electronic documents and presentations for a homework activity and expecting them to seek out extra resources in preparation for the next lesson was 'prompting them to keep this in the front of their minds'.

The main casualty of lesson pacing going awry appeared to be time for pupil discussion, reflection and analysis and for summary, consolidation and closure by teachers – important features of lessons both with and without ICT use but perhaps even more critical in a context where less whole class teaching tends to be employed. It is considered ideal by some to include introductory and closing plenaries in ICT-supported lessons, setting the scene and drawing together key points: "Ideally, individual or group activities finish in good time for work to be displayed and discussed, ensuring that key learning points are reinforced" (Becta, 2002, p.3). As the talk about whole class discussion indicated, teachers agreed with this but found it difficult in practice. Nevertheless, lesson planning perhaps needs to take more account of the facts that productive discussion and pupil reasoning take time; using ICT (especially the Internet) is often slower for technical reasons and efficient use is directly dependent on careful (albeit time consuming) advance preparation and conscious attempts to maintain lesson pace. Teachers further highlighted the importance of ensuring that pupils can complete work within the time frame of a lesson in order to maintain their motivation (DD, DR, OT). A degree of caution is advisable here, since in one Geography project (FC/DR), the lessons observed were considered by our subject specialist to be too short to develop pupil thinking and consolidate understanding; prioritising task completion meant that learning opportunities were missed. Pacing lessons supported by ICT is thus a complex task involving some advance preparation and trial-and-improvement of lesson plans, but a critical *balance between maintaining efficient ways of working and a focus on learning objectives – and allowing enough time for discussion, reflection and consolidation of subject learning.* (Flexibility is also central since technical problems may sabotage the most carefully planned lessons.)

Development in teachers' pedagogical thinking

The ways in which teacher's 'practical theories' concerning the use of ICT in teaching and learning in their classrooms were found to develop over the course of their projects have been charted elsewhere (Deaney & Ruthven, in preparation). Here we reflect briefly on the impact of using ICT in these ways upon teacher-researchers' pedagogical thinking, where clues to this arise. For one Science teacher, it was
'business as usual' in the sense that aspects of effective practice remained pertinent:

> I feel one of the key things about using any form of ICT is that the ICT itself is just a tool; all of your other teaching practices should still come into play so there should still be some kind of differentiation, looking at the learning styles and trying to apply thinking skills... (OT)

This is convincing although it does not address the specific pedagogic demands which may arise when using ICT. For another individual, ICT-supported lessons were described as having enabled – indeed provoked – a more reflective, reactive approach to the design of learning activities than can normally be employed in classroom teaching:

> There has been a sense that I've been going from lesson to lesson, reflecting on what they've done and developing, rather than sitting down at the beginning and saying, 'Well they're going to do this, this, this and this.' Which I could do if we were just working in the classroom. (DD)

Of course, this reflectiveness may be attributable to participation in the research project; indeed it seems probable that teachers' involvement – and particularly the demands upon them to report formally on their projects – served to discipline their thinking about using ICT. It is nevertheless notable that there was evidence for several teachers choosing to develop new forms of pedagogy, as in some of the examples above of mediating strategies used to structure

activity in the context of ICT use. About half of the teachers devised deliberate strategies aimed at focusing on subject content; while 'focusing' (Wood, 1994) describes how teachers draw attention to critical features of a task more generally, using ICT can evidently add an extra layer of obliqueness or distraction. However, as well as these hindering effects, it offers unique and exploitable opportunities such as creative manipulation of text or graphic images or electronic annotation, as illustrated above. The teaching of generic search skills is another example of evolving pedagogy associated with ICT use – directed in this case towards supporting effective navigation of digital pathways that lead far beyond classroom-based resource provision. Similarly, awareness of the teacher's role in actively supporting collaborative working is beginning to grow.

The use of ICT can act as a catalyst in stimulating teachers and pupils to work in new ways, some of which clearly draw on established practice but successfully extend and adapt it to this new context. For example, responding to the physical features of the setting – in particular, the shift in focus of attention away from the teacher and towards the (physically dominant) screens of individual or shared machines – and to the increased scope, easier accessibility and greater interactivity of electronic resources, seems to encourage more student-regulated learning as teachers' role as 'knowledge provider' diminishes. The decrease in formal teaching and greater pupil control in turn mean that teachers employ additional pedagogic strategies for supporting, guiding and facilitating learning and ICT-supported research activity. The latter condenses the processes of exploration and information finding, requiring teachers to devise ways of effectively managing and mediating pupils' interactions with electronic resources. Other factors such as the desire of reflective practitioners to introduce innovation and to prepare their pupils for future use of technology may also play a role. (See Deaney & Ruthven, in preparation, Ruthven et al., submitted, for more detailed perspectives on how using ICT can enhance teaching and learning.)

Other documented examples of how teachers are successfully responding to the unanticipated events which arise when using ICT (particularly related to its expedition and enhancement of work production) included making available printed records and other resources, and learning to adjust the pace, approach and balance of lesson activities. In some cases there was a growing awareness of the need for actually increasing focus on certain aspects of established practice, for example recognition of the roles of whole class discussion and modelling complex techniques. Holding onto other successful subject practices was not deemed to be incompatible with using new tools. For instance, one teacher found that the most focused research-based lessons were where students used electronic and non-electronic sources in conjunction (supplementing or checking on-line information using book stock: LLR). RE found that integrating computers with use of exercise books was productive and helped pupils to focus the points they recorded:

> …the idea of using the exercise books in conjunction with their work on the screen, I thought that worked. I didn't want them to actually type that much, I didn't want them to deal with too much information on screen and then print it, save it to file, I wanted them to transfer it to their exercise book and I felt that the stuff that was going into the exercise book did reflect quite a good amount of work being done just through manipulating text on screen. So I was very pleased with that.

While teachers were clearly building and elaborating upon established practice in some ways, however, the subject specialists indicated that their use of ICT overshadowed effective subject pedagogy in some cases. Appreciation of how to use ICT appropriately (rather than as an end in itself) was considered a problem and all of the specialists commented that the potential of ICT was not fully exploited within the lessons observed. Similarly, Harrison (in press) maintains that teachers leave behind the rigour of ordinary practice (for example the critical selection and analysis of evidence in History) and their expert pedagogical skills when using

ICT. In this study we saw some lost opportunities for teachers to move pupils' thinking on through in-depth explanation, sharing and evaluation of key ideas, exploring and refining hypotheses through searching, etc. However, six teachers explicitly mentioned that they were developing and trialling a new activity (AI, KE, LR, OT, OL, VM) and some were inexperienced in using ICT in the classroom. They nevertheless entered admirably into the spirit of trying new things:

> I'm not worried about trial and error. If it fails I'll do it differently or I won't do it at all again. (AI)

It may be that teachers need to take a step back before they can progress in this arena. Inevitably they become novice practitioners again in the sense that they have not yet developed grounded ways of integrating ICT into subject practice nor has their thinking been significantly influenced by the availability of new technology. Teacher expertise is situated within certain subject practices and cultural change can be construed as "a gradual process of pedagogical evolution" (Hennessy et al., submitted, Kerr, 1991, Loveless et al., 2001). This involves development, trialling and refinement of successful activities, approaches and strategies, and critical reflection upon their underlying aims and principles.

Summary and conclusions

The use of ICT was observed within a wide range of very different contexts – varying by subject practice, pupil age and ability group, pedagogic outlook, activity type etc. (All of these details from such a number of case studies cannot possibly be presented in a single paper but they are by and large represented in the teacher-researchers' case reports, lesson plans and accompanying materials to be found on the TiPS website.) Nevertheless a number of general conclusions can be drawn here concerning the ways in which teachers create the conditions for successfully supporting learning using ICT.

We begin by concurring with Finlayson et al (2002) that the pedagogical role is not diminished through using technology but that its nature changes; teachers intuitively draw on and modify many aspects of established practice in their continuing concern with providing motivating learning activities (Denning, 2001). Using the guided participation framework to interpret the findings leads to the conclusion that the teacher takes both *proactive* and *responsive* roles in assisting pupils and supporting their learning and progression. The very physical deployment of ICT in the schools where these teachers worked often assumed that these roles would be less directive than during other classroom activity, for example in the absence of facilities for classroom projection. Consequently, the teacher's responsibility for selecting resources which contribute to an identified learning purpose (that is matched to pupils' age and ability) – and *carefully designing interactive learning activities* involving constrained tasks with clear objectives (an important but overlooked form of scaffolding: Anghileri, 2002) – becomes greater. The teacher's role becomes more demanding in some ways, both in terms of *advance thinking, design and preparation*, and in *facilitating learning in action*. Classroom activity and resources need to be structured in ways which *simultaneously encourage reflection and analysis and maintain pupils' focus on subject learning* – in the face of distracting technical issues – and allow them to actively manage their own motivation and participation (cf. Rogoff, 1990, Wood, 1994). Thus, as pupils' roles become more autonomous, teachers need to encourage and *support pupils in acting and thinking independently*. This means ***strategically balancing freedom of choice, pupil responsibility and self–regulated learning (in conjunction with responsive teacher assistance) with structured activity, focused enquiry and proactive teacher guidance.*** Similarly, the peer group plays a strong mediating role in the context of technology-based learning, where there consequently appears to be more demand for *organising and managing peer collaboration*. The teacher's critical role in shaping classroom discourse and establishing norms for active student participation (Cobb *et al*., 1991)

may in this context include *developing a stronger culture of sharing ideas and reflections* – with working partners and during whole class discussion (the role of which currently appears to be under-developed in the context of ICT use).

Teachers also found it helpful to *support learning and revision away from the technology* by making available printed records and non-electronic resources. *Integration with other complementary and ongoing teaching and learning activities* is desirable in many situations too. Our conclusions relate particularly to research activities using the Internet, a common theme among our teachers. The consensus view was that completely open-ended searching can be fruitless but that a degree of choice is motivating to pupils; *offering some choice within a pre-selected range of sites* can therefore provide a compromise solution here. It was acknowledged that *developing new pupil skills for information handling and critical analysis* is necessary if the process and outputs of research using ICT are to be worthwhile and more attention could usefully be directed towards researching the optimal ways of doing this. The age and ability of pupils are clearly factors of influence on both the appropriate degree of control during research activity and on the degree of support required by pupils developing new skills. And while it has always in fact been desirable to differentiate activities for individual needs (educational, cultural, linguistic), now teachers may have to *recognise and build upon pupils' acquired technical expertise* as well. Moreover, they need to *devise ways of assessing ICT-supported learning.* Finally, the very real threat of technical difficulties arising mean that teachers are learning to *pace ICT-based lessons realistically – balancing efficiency, focus and task completion* (linked to pupil motivation) with *time for discussion and consolidation of learning*. They have also found that *trialling* lesson plans, *devising back-up plans* and some in-built *flexibility* are advisable.

To conclude, teachers' evolving roles in the context of incorporating ICT use into subject teaching and learning are highly complex and demanding. They require a balance of proactive and responsive strategies for mediating interactions between pupils and technology, and these in turn involve increased levels of interaction with smaller groups of students. Pupils accordingly need to act more independently, take more responsibility for managing and pacing their own learning and work at developing new skills for peer collaboration, critical selection and interpretation of electronically derived information. While the findings provide some support for the rhetoric concerning teachers' and pupils' new roles, the complexity of these evolving roles – and the need for identifying what kinds of support teachers may require in meeting these multiple demands – are only just beginning to be recognised.

Acknowledgements

Thanks to Louise Goodwin, Alison Craig, Theresa Daly and above all, to the teacher participants for their various contributions to carrying out this research. We are also grateful for the insightful comments of the subject specialists who reviewed our data (Sue Brindley, Christine Counsell, Bill Nicholl, John Raffan, Liz Taylor). The Wallenberg Research Centre for Educational Improvement supported the research partnership and this particular project.

References

Anghileri, J. (2002) Scaffolding Practices that Enhance Mathematics Learning in: E. Nardi (Ed) *26th Conference of the International Group for the Psychology of Mathematics Education* (Norwich, School of Education and Professional Development, University of East Anglia).

Barton, R. (1997) Computer-aided graphing: a comparative study, *Journal of Information Technology for Teacher Education*, 6(1), pp. 59-72.

Barton, R. & Still, C. (in press) Planning, teaching and assessment using computer-aided practical work (ch.4), in: R. Barton (Ed) *Teaching Secondary Science with ICT* (Cambridge, Hill McGraw).

Becta (2002) Young People's Use of ICT(Coventry, Becta).

Bowell, B., France, S. & Redfern, S. (1994) *Portable Computers in Action* (Coventry, NCET).

Bruner, J. (1985) Vygotsky: a historical and conceptual perspective, in: J. Wertsch (Ed) *Culture, Communication and Cognition: Vygotskyan Perspectives* (Cambridge, Cambridge University Press).

Cobb, P., Wood, T. & Yackel, E. (1991) Classrooms as learning environments for teachers and researchers, in: N. Noddings (Ed) *Constructivist Views of the Teaching and Learning of Mathematics* (Reston, NCTM).

Cognition and Technology Group at Vanderbilt (1996) Looking at Technology in Context: a framework for understanding technology and education research, in: R.C. Calfee (Ed) *Handbook of Educational Psychology* (New York, Macmillan Library Reference).

Collins, J., Hammond, M. & Wellington, J. (1997) *Teaching and Learning with Multimedia* (London, Routledge).

Cuban, L. (2001) *Oversold and Underused: Computers in the Classroom* (Cambridge, Harvard University Press).

Deaney, R. & Ruthven, K. (in preparation) Practical theories of technology-integrated pedagogy: an analysis of 10 cases from English secondary schools

Deaney, R., Ruthven, K. & Hennessy, S. (2003) Pupil perspectives on the contribution of information and communication technology to teaching and learning in the secondary school, *Research Papers in Education,* 18 (2) pp. 141-165

Denning, T. (2001) Information and Communications Technology and pedagogy, *Journal of Information Technology for Teacher Education*, 10(Special Issue Nos 1 & 2, Editorial), pp. 3-6.

DfE (1995) *Information Technology/English/Science/Mathematics in the National Curriculum* (London, HMSO).

DfEE (1999) *The National Curriculum* (London, HMSO).

Eisner, E. (1991) *The Enlightened Eye: Qualitative Inquiry and the Enhancement of Educational Practice* (New York, Macmillan and Company).

Ellis, V. (2001) Analogue clock/digital display: continuity and change in debates about literacy, technology and English, in: V. Ellis (Ed) *ICT Pedagogy and the Curriculum - Subject to Change* (London, Routledge).

Finlayson, H., Wardle, J. & Rogers, L. (2002) Integration of ICT within science lessons (grades 5-10)*National Association for Research in Science Teaching Conference* (New Orleans,

Glaser, B.G. & Strauss, L.L. (1967) *The Discovery of Grounded Theory: Strategies for Qualitative Research* (Chicago, Aldine).

Goodson, I.F. & Mangan, J.M. (1995) Subject cultures and the introduction of classroom computers, *British Educational Research Journal*, 21(5), pp. 613-628.

Hadley, M. & Sheingold, K. (1993) Commonalities and distinctive patterns in teachers' integration of computers, *American Journal of Education*, 101, pp. 261-313.

Hammond, M. (2001) Using the Internet in secondary schools: implications of a case study(Coventry, Centre for New Technologies Research in Education Occasional Paper, University of Warwick).

Harrison, S. (in press) The use of ICT for teaching history: slow growth, some green shoots; findings from HMI inspection 1999-2001, in: T. Haydn (Ed) *History, ICT and Learning* (London, Routledge).

Hennessy, S., Fung, P. & Scanlon, E. (2001) The role of the graphic calculator in mediating graphing activity, *International Journal of Mathematical Education in Science and Technology*, 32(2), pp. 267-290.

Hennessy, S. & Murphy, P. (1999) The potential for collaborative problem solving in D&T, *International Journal of Technology and Design Education*, 9(1), pp. 1-36.
Hennessy, S., Ruthven, K. & Brindley, S. (submitted) Teacher perspectives on integrating ICT into subject teaching: Commitment, change and caution.
Kerr, S.T. (1991) Lever and fulcrum: educational technology in teachers' thought and practice, *Teachers College Record*, 93(1), pp. 114-136.
Kozulin, A. (1998) *Psychological Tools: A Sociocultural Approach to Education* (London, Harvard University Press).
Lagrange, J.-B., Artigue, M., Laborde, C. & Trouche, L. (2001) A meta study on IC technologies in education: towards a multi-dimensional framework to tackle their integration in: M. Van den Heuvel-Panhuizen (Ed) *25th Conference of the International Group for the Psychology of Mathematics Education* (Utrecht,
Loveless, A., DeVoogd, G.L. & Bohlin, R.M. (2001) Something old, something new... Is pedagogy affected by ICT?, in: V. Ellis (Ed) *ICT, Pedagogy and the Curriculum* (London and New York, RoutledgeFalmer).
Lynch, O. (2001) Welcome Speech*Building an ICT Research Network: Helping to Create Schools of the Future* (Barbican Centre, London, Becta).
McFarlane, A. (2001) Perspectives on the relationships between ICT and assessment, *Journal of Computer Assisted Learning*, 17(3), pp. 227-234.
McGhee, R. & Kozma, R. (2001) New Teacher and Student Roles in the Technology-Supported Classroom*AERA* (Seattle, Washington, USA,
Means, B. & Olson, K. (1997) *Technology and Education Reform* (Washington DC, Office of Educational Research and Improvement, US Department of Education).
Mercer, N. (1995) *The guided construction of knowledge : talk amongst teachers and learners* (Clevedon ; Philadelphia, Multilingual Matters).
Moseley, D., Higgins, S., Bramald, R., Hardman, F., Miller, J., Mroz, M., Harrison, T., Newton, D., Thompson, I., Williamson, J., Halligan, J., Bramald, S., Newton, L., Tymms, P., Henderson, B. & Stout, J. (1999) Ways forward with ICT: Effective Pedagogy using Information and Communications Technology for Literacy and Numeracy in Primary Schools(Newcastle, Newcastle University, Durham University and CEM Centre, Durham University).
Newton, L.R. & Rogers, L. (2001) *Teaching Science with ICT* (London, Continuum).
Noss, R. & Hoyles, C. (1996) *Windows on Mathematical Meanings* (Dordrecht, Kluwer).
Noss, R. & Pachler, N. (1999) The challenge of new technologies: doing old things in a new way, or doing new things?, in: P. Mortimore (Ed) *Understanding Pedagogy and Its Impact on Learning* (London, Paul Chapman).
O'Malley, C. (1995) *Computer Supported Collaborative Learning* (New York, Springer-Verlag).
Ofsted (1999) Standards in the Secondary Curriculum 1997/98: Information Technology(London, Office for Standards in Education).
Ofsted (2001) ICT in Schools: The Impact of Government Initiatives, An Interim Report April 2001(London, Office for Standards in Education).
QCA/DfEE (1999) Key Skills Units, Levels 1-3(London, Qualifications and Curriculum Authority).
Rogers, L. (in press) Integrating ICT into the curriculum (ch. 9), in: R. Barton (Ed) *Teaching Secondary Science with ICT* (Cambridge, Hill McGraw).
Rogoff, B. (1990) *Apprenticeship in thinking: cognitive development in social context* (Oxford, Oxford University Press).
Rogoff, B. (1995) Observing sociocultural activity on three planes: participatory appropriation, guided participation, and apprenticeship, in: A. Alvarez (Ed) *Sociocultural Studies of Mind* (Cambridge, Cambridge University Press).
Ruthven, K. & Hennessy, S. (2002) A practitioner model of the use of computer-based tools and resources to support mathematics teaching and learning, *Educational Studies in Mathematics*, 49(1), pp. 47-88.
Ruthven, K., Hennessy, S. & Brindley, S. (submitted) Teacher representations of the successful use of computer-based tools and resources in teaching and learning secondary English, Mathematics and Science.
Schofield, J.W. (1995) *Computers and Classroom Culture* (Cambridge, Cambridge University Press).

Scrimshaw, P. (1993) Cooperative writing with computers, in: P. Scrimshaw (Ed) *Language, Classrooms and Computers* (London, Routledge).
Scrimshaw, P. (1997) Computers and the teacher's role, in: N. Davis (Ed) *Using Information Technology Effectively in Teaching and Learning* (London, Routledge).
Selinger, M. (2001) Information and communications technologies in representations of mathematics, in: V. Ellis (Ed) *ICT, Pedagogy and the Curriculum* (London, Routledge).
Selwyn, N. (1999a) Differences in educational computer use: the influence of subject cultures, *Curriculum Journal*, 10(1), pp. 29-48.
Selwyn, N. (1999b) Why the computer is not dominating schools: a failure of policy or a failure of practice?, *Cambridge Journal of Education*, 29(1), pp. 77-91.
Watkins, C. & Mortimore, P. (1999) Pedagogy: What do we know?, in: P. Mortimore (Ed) *Understanding Pedagogy and its Impact on Learning* (London, Paul Chapman).
Watson, D.M., Cox, M. & Johnson, D. (Eds.) (1993) *The ImpacT Report: An Evaluation of the Impact of Information Technology on Children's Achievements in Primary and Secondary Schools* (London, Department for Education and Kings College London).
Williams, D., Coles, L., Wilson, K., Richardson, A. & Tuson, J. (2000) Teachers and ICT: current use and future needs, *British Journal of Educational Technology*, 31(4), pp. 307-320.
Wood, T. (1994) Patterns of interaction and the culture of mathematical classrooms, in: S. Lerman (Ed) *Cultural Perspectives on the Mathematics Classroom* (Dordrecht, Netherlands, Kluwer Academic Publishers).