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## Emerging teacher strategies for supporting subject teaching and learning with ICT

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## ABSTRACT

This paper reports on a collaborative programme of small-scale projects undertaken by 15 teacher-researchers using various forms of computer-based ICT to support subject teaching and learning. The participants developed, trialled and refined new pedagogic approaches and activities in six curriculum areas (English, Classics, Design Technology, Geography, History, Science) at secondary level. A cross-case analysis was conducted using lesson observations, follow-up teacher interviews and teachers' research reports.

A set of proactive and responsive pedagogic strategies for supporting pupils' use of ICT was identified. These included exploiting the technology in new ways and circumventing its associated constraints. The strategies emerging illustrated how teachers structured activities judiciously; supported, guided and challenged; encouraged pupil collaboration, experimentation, reflection and analysis; avoided floundering and maintained a focus on subject learning; integrated use of other resources; developed information handling skills. These strategies and the gradual withdrawal of teacher support over time served to increase pupil participation and responsibility for their own learning. Pupils themselves played a role through opportunistically soliciting teacher assistance and feedback.

## INTRODUCTION

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 patterns of classroom interaction. However, development of appropriate pedagogy for integrating use of ICT in subject teaching has seemingly lagged behind the massive investment in provision of hardware, software and teacher training in using ICT which fuels the official discourse about transforming learning. Previous research indicates that teachers using computers increasingly see themselves as facilitators of learning. Pupils are correspondingly perceived as becoming more independent, active and responsible learners. The emphasis on personal knowledge building by students means that providing *opportunities and time for discussion, reasoning and interpretation* is becoming even more important. However effective pedagogy of this kind is currently underdeveloped in typical classroom settings according to Ofsted and is a priority for policymakers and educators. Evidence from Ofsted further indicates that pupils lack efficient strategies for searching digital databases and the Internet and that they continue to present unprocessed information.

In this study we compare the rhetoric of transformation with classroom reality – in terms of the pedagogic strategies emerging for using technology in secondary subject teaching. We investigate whether and how the teacher plays a critical role in selecting learning resources and in structuring, sequencing, monitoring and assessing learning with ICT. This is achieved 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.

## 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 teacher-researchers from 5 maintained (non-selective) secondary schools. The schools formed part of a research partnership programme with the University of Cambridge

through which research-based processes of school improvement and professional development were being explored and technology integration had been prioritised. The schools were located within a 50-mile radius of Cambridge and, by standard indicators<sup>i</sup>, were relatively socially advantaged and academically successful. There was some variation in ICT provision amongst the participating schools, one of which had specialist Technology status. A few teachers had access to a set of dedicated desktop computers in their subject area but technology use mostly depended upon opportunistic access to generic computer rooms. These were heavily scheduled for other purposes and only one had projection facilities. Pairs of teacher-researchers within the same department were encouraged to work collaboratively on case study projects; 5 collaborative and 5 individual projects emerged. These teachers volunteered to participate in the project in order to develop their classroom practice in using ICT; their prior experience of this varied considerably.

### *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 upon established teaching and learning approaches, they typically involved significant development of the role of ICT within these. Participants were organised into groups of three to five members pursuing similarly themed projects across schools; these covered six curriculum areas and involved pupil groups from Years 7-13, aged 11-18 (see summary in Table 1). Preparation of teaching and research plans was supported by each group meeting with the university team on five occasions for 2-3 hours on average. Guidance was also offered to support writing up and draft reports received feedback before submission. The teacher-researchers were aided by small grants<sup>ii</sup> intended to fund support for their work, including some release from normal duties.

<Table 1 here>

### *Investigative strategy and cross-case analysis*

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, and they provided a shared experience on which the teacher and researcher could jointly reflect. 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, specifically regarding the contribution of ICT use to lesson success. Observations and interviews were audiotaped and transcripts were returned to participants for corroboration. Lesson plans, activity sheets, samples of student work and digital photographs provided additional records, complementing the researcher's observation notes and pen-portrait depicting classroom setting and activity.

An overarching analysis across the very different classroom contexts of our case studies drew on all of the above data sources. Findings of each case study were validated by subject specialists within the Faculty. Interview transcripts were imported into a computer database and common themes were identified.

## EMERGING STRATEGIES OF TEACHER MEDIATION

### *Task design and structuring of classroom activity with ICT*

#### *Exploiting and complementing established practice*

Our findings have confirmed, unsurprisingly, that teachers using ICT in the classroom intuitively draw on and modify many aspects of established practice in their continuing concern with providing motivating learning activities. However, there were some notably different forms of interaction, teaching styles and mediating strategies emerging, and it is these which are explored in this paper.

The first key feature of *task design* was the *integration of electronic resources with other resources* and thus with valued *complementary* aspects of the established classroom culture. The teachers studied all perceived that using ICT offered some unique features and sources of information unavailable elsewhere. At the same time, conventional resources such as textbooks can still play a useful role. For example, OT integrated textbook work at the beginning of the activity "to emphasise the fact that the Internet isn't everything, that you can get information from books still, they aren't completely redundant". Another teacher found that the most focused research-based lessons were where students combined different sources, supplementing or triangulating on-line information using book stock (LL/Rep). Note that specific pedagogical strategies for incorporating Internet resources into classroom practice – including enhancing and complementing other resources – are the focus of an in-depth analysis of the five Internet-based projects reported elsewhere.

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 unavailable electronically. 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. Balancing and combining use of electronic and other resources was a common interview theme and was embodied in the notion of *multisource learning*. AY argued that the Intranet site created was itself multisource; it offered different historical perspectives through battle accounts, biographical information, letters, diaries, posters, pictures.

#### *'Pre-structuring' of tasks supporting pupil-technology interaction*

A prominent feature of initial task design was the *'pre-structuring' of activity via clear, focused, constrained tasks*. Indeed lesson success was commonly attributed first and foremost to carefully defined aims and tasks, and resource sheets in paper or electronic form.

Several teachers had clearly learned from experience that too much open-endedness in ICT-supported activity was problematic. They had therefore introduced more structure, particularly into research tasks. AY told us that at the start of the project they "left too much open and... the kids felt a lack of clarity" whereas the task observed worked better because it was "well-structured and they went from point to point to point". Similarly, OL felt that constraining the task was important to avoid time wasting by pupils and so he 'focused on [a few] pictures and told them which ones'. One Science teacher learnt during the lesson observed that his worksheet needed to offer more structure and guidance when introducing the task, providing sufficient information for students to start research work straight away and "point[ing] them more in a direction that we want them to

look at.” His report concluded that successful Internet use “relies on well-planned and structured lessons, with clear objectives that enable differentiated activity” (OT/VM Rep).

Teachers’ experiences also highlighted opportunities to assist pupil navigation during research activity, and some teachers had devised ways of using electronic resources to do this. 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). Providing salient hyperlinks within worksheets was also 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).

Advance preparation proved especially critical for Internet research, where *setting clear parameters for electronic searches* and *pre-selecting websites* helped pupils to obtain useful, accessible and relevant information. Similarly, *provision of an Intranet* constituted a bounded database of reliable, accessible information. 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 several teachers as generally less focused, less age-appropriate and ability-specific, and less reliable and predictable than that from other sources, which is often carefully pre-filtered. Teacher *filtering of information beforehand* was deemed essential. Another strategy was to impose *time limits on searching*.

### ***Teacher and pupil roles in structuring technology use***

#### *Proactive and responsive strategies for guiding and shaping pupil activity*

A picture of changing patterns of classroom interaction emerged from our analysis, in the form of evidence of greater teacher involvement in pupil activity and more teacher-pupil discussion. Six teachers recounted how they circulated methodically around the class and were able to interact productively with more – or all – individuals or small groups when using ICT. For example, for DR, “it was a lot easier to go round”, he “managed to focus on every pair of children” and “took a larger role in their decisions”. Using the Internet in class similarly gave VM the opportunity to go around and “just show an interest in what they’re doing”, normally unachievable in a class of 28 students.

The most significant pedagogic shift reported and observed was towards the teacher providing *support, guidance and facilitation* in terms of offering ideas, suggestions or help. These prominent mediating strategies were associated with the teacher “taking more of a back seat and being the facilitator” (RA). Some teachers described their role during the lesson in terms of introducing the task, then focusing the pupils:

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)

The more supportive and facilitative teacher role was continually contrasted with that of the traditional knowledge giver. One teacher described her role as “answering questions that they might have and trying to point them into the right direction rather than teaching from the front” (VM).

#### *Evaluating and accommodating learners’ shifting needs: the role of opportunistic interaction*

Several teachers talked about *probing, questioning, challenging and monitoring* pupils as they moved around the class. These kinds of activities were *proactive* in the sense that they often took

place during the systematic circulating described above, but they could also be construed as *opportunistic teacher intervention*, whereby teachers *adjusted their support contingently upon pupils' progress*. For example, although the Classics teacher described her role when using ICT for a research activity as “bombing about”, it actually involved assessing the value of students' chosen websites and discussing topic titles, questioning and guiding students towards generating a specific question.

Linked to the increased emphasis on informal interaction was more *opportunistic help seeking* by pupils. This was observed in many lessons and commented on by one English teacher: “they quite often will ask something because I happen to be there” (AI). She described how the increased opportunity to provide active coaching and more immediate, informal feedback (with less physical intrusion) than during writing by hand meant that pupils were less reluctant to ask questions and more likely to respond to suggestions, whereas they took little notice of ‘a passive written statement’. These findings reflected a pupil desire for more interaction and teacher input when working with ICT. Despite being less reliant on the teacher, pupils were reportedly keen to engage with their teacher and to receive reassurance (AI/Rep). 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 and our observations.

While our primary focus concerns the pedagogical strategies which teachers use to mediate between learners and the technology, our observations show how the machine can also act as a tool in mediating between teacher and pupil. The History project teachers described in their report how “ongoing dialogue between the pupils” made it “easier to intervene” and discussion of on-screen work “fosters a more collaborative approach between pupils and teachers” [OL/AY/Rep]. Interim drafts of activity visible on the screen, and pupil notes, may also be useful indicators for assessment. 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” (AY). 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”.

#### *Increasing the role of interactive whole class teaching*

Against the higher level of individual teacher-pupil interaction and lower level of information dispensing associated with using ICT, teachers were less certain about the role of whole class interactive teaching and the sharing of agency with pupils which it denotes. One History teacher told us that “when you're teaching with computers... you tend to spend less time talking” (maximising its use) but he was “not sure whether that's right” (AY). 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 observed in a Geography lesson could similarly be construed as inefficient (DR). The findings additionally illustrated the power of complementing technology-based individual or pair work by exploring complex issues within a larger group discussion. In one English case (LR/RE Rep), using ICT assisted the initial deconstruction of text, whilst 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, enable sharing of ideas, and for establishing a clear focus initially. Another four felt

that their lessons would have benefited from additional discussion. The research team and subject specialists identified some further unexploited opportunities. These findings point to the conclusion that the role of whole class interactive teaching – and the opportunities it provides for collaborative reasoning and interpretation of shared experience – are currently under-developed in the context of ICT use.

One direction which development might take is further use of *modeling*, 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 three teachers explicitly acknowledged its utility. One English teacher (AI) planned to use computer projection to facilitate sustained whole class discussion of writing and redrafting, modeling 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 writing structure, i.e. "modeling what I would do if I was writing that piece".

### *Supporting self-regulated active learning*

#### *Promoting active student participation, experimentation and independent thinking*

A newly emerging role for teachers involved *encouraging active participation in ICT-supported activity* (described in eight interviews and one further case report). This built upon their belief that using ICT can enhance learning and motivation through the opportunities it provides for self-regulated, active learning, i.e. for knowledge building rather than transmission, and for pupils working at their own pace. Exploiting these using strategies involving "little adult intervention" and pupil freedom to choose their methods of working and find "as much information as they like or as little" (OT) "meant that they could be discoverers rather than followers" (RA). In contrast, traditional "chalk and talk" lessons involved more teacher direction and "spoon feeding" according to six interviewees.

Teachers generally considered themselves to be *supporting student-regulated learning* through facilitating information finding and developing understanding, e.g. by providing opportunities for experimentation, reflection and analysis. The emerging strategy (in eight cases) was one of *prompting* pupils with the aim of *encouraging them to think for themselves* and find their own solutions:

This was more designed as... a thinking skills lesson... going around just probing them and giving them stimuli but not giving them answers... it would just be prompting more questions hopefully. (OT)

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 ... 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". (KE)

#### *The critical role of teacher guidance and support*

The term 'independent learning' was commonly but inconsistently used in the interviews and its implications for pedagogy were 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 clearly implied. While this 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). 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 teachers continually emphasised the importance of their guiding and supportive role and a widely shared view (by 7 teachers) expressed that this kind of teacher input was essential when pupils were using ICT, even in the context of more independent working. One History teacher reported:

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 [meeting] the aims of the lessons. (OL)

Thus, increased pupil self-regulation was not considered to diminish – and can actually strengthen – the need for *active teacher input and intervention*. In fact, in most cases it was the same teachers who reported taking a facilitating role yet less pupil reliance on teacher intervention. For instance, one teacher described his new role as one of helping children find information for themselves, with prompts but largely under their own control; he 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). In some cases, pupil control and choice were very limited in practice despite an ‘independent learning’ setup. By contrast, two teachers recognised that too much open-endedness had proved confusing for pupils. These cases highlighted the importance of teachers being ‘quite active’ in *guiding pupil activity to pre-empt floundering* or off-task wandering.

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). Several teachers recognised this and expressed a desire for a *balance between teacher direction and providing opportunities for “pupil-centred” learning*. The central issue here was summarised by the reflection of one English teacher (YL) 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).

### ***Maintaining focus on subject learning***

Related to the above discussion is another important strategy described by about half of the participants: *focusing on subject content*. This strategy 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. Deliberate strategies are thus needed to help pupils avoid overly mechanical uses of ICT which can be obstructive.

#### ***Focusing on subject content through exploiting benefits of ICT***

Our first form of ‘focusing’ describes how teachers positively exploited certain sophisticated features of ICT in order to render particular 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 for explaining difficult words (AI). Text from a Shakespeare speech was deconstructed and manipulated in another lesson through creating a paragraph of alphabetically ordered component words; this focused pupils on key themes through looking at repetition or alliteration



(AI). Using ICT was also considered to enable rapid manipulation of text and formatting by students themselves, 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’ (AI). The technology thus became a medium through which pupils could ‘reflect’ their understanding (RE).

Another example of this form of focusing was exploitation of the ability to manipulate and enlarge pictures in a History project. This 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 were actually thinking for themselves first... 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)

### *Avoiding pupils' distraction and obsession with presentation*

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. This was a particularly important issue in English but arose elsewhere too, for instance Geography where pupils could easily “get wrapped up in a beautiful title or lots of pictures and... lovely borders” (DR). Keeping pupils on task and avoiding playing around was important in order to maintain the focus (e.g. KE). One English teacher described how experimenting with different colours and fonts could lead to ‘a complete mess’ and ‘meaningless outcomes’ (RE). Another English teacher used both whole class discussion and prompting of individuals to successfully stimulate pupils' thinking about key issues concerning format and presentation mode. Pupils moved beyond wanting to ‘beautify the work and get away from pen and ink’ towards an ‘awareness of how they tailor language [to] audience and purpose’ (YL).

### *Supporting learning away from the technology*

A further emerging constraint associated with ICT-supported activity was the potential lack of physical outputs. Teachers adapted to this by providing *other text-based resources or student records – printouts of activity or written notes/sketches* – for later reference back to lesson content. These were considered especially important to support learning and for subsequent revision. One English teacher espoused the value of integrating computer work with use of exercise books in his lesson, where students successfully recorded points that were ‘very focussed and very sort of pithy’ (RE). However, progress may be hindered (as observed in one Science lesson) because students do not always conform to teacher expectations that they will take notes or print out at appropriate times, so very explicit guidance is required.

Regular printing was also used to provide feedback, for instance in Design Technology where students could see if their drawings were to scale (JN). The precise reasons for the limited degree of printing observed generally remain unclear but they no doubt include technical issues and lack of access to printers, cost, and perhaps in a few cases, low priority is ascribed to printed records. Ironically, a printer malfunction 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.

## *Increasing pupil agency and responsibility for learning*

### *Withdrawing support and increasing pupil responsibility*

Teachers were found to be developing various kinds of strategies for fostering a greater sense of personal agency. Five used the technique of *gradually withdrawing support*. This included progressively more open-ended Web searches, involving “less spoon-feeding” in terms of providing Web addresses and directing searches (FC). It was sometimes embodied in the use of progressively less structured tasks of other kinds, particularly for the most able children: their worksheet for orthographic projection “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 (JN). For KE, use of circuit simulation software meant that “the brightest ones could connect things up and could work at their pace and the less able were still able to achieve and get the end result - although through a more guided means.”

Strategies which were again *exploiting particular benefits of ICT* served to reduce the need for some forms of teacher input and detailed feedback, and to increase pupil independence. A Design Technology teacher asserted that using ICT for constructing virtual circuits releases the teacher from having to go around saying, "That's not going to work". It enables pupils to visualise for themselves what happens if components are connected wrongly and “to make mistakes and learn from it” (KE). Greater independence was clearly valued by teachers generally, and particularly where students were confident enough to select their own ICT resources and utilise them to develop their own ideas, as in this English example:

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)

Pupil independence and confidence to explore by themselves were considered by three teachers to develop over time as ICT skills increase, allowing teacher support to decrease:

The vast majority... got into the task without relying on whether the adults were present to move them on. And that is a very, very great contrast with the first lesson... where they were reluctant to even make some simple searches. (DD)

### *Developing pupils' information handling skills and critical literacy*

Another key strategy is that of *developing pupil skills for finding information*, particularly for searching the Internet efficiently using keywords. One teacher described how pupils developed confidence in searching during the project and how the open-endedness of Internet surfing increased pupil motivation, especially for 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 [encyclopaedic database], it's a bit like buying fish in a shop... (DD)

For this teacher, *providing or negotiating keywords and hyperlinks* proved to be the most efficient and useful strategies in keeping pupils focussed, although they still needed to be able to select suitable sites from the search results (DD/Rep). Two further strategies proved effective in avoiding pupils' distraction and frustration caused by extraneous information such as advertising banners and optional links on a chosen site: (a) helping pupils to focus on the search for key words on the page, and (b) improving legibility of difficult sections of text by pasting it onto a plain background.

By contrast, another teacher-researcher (LL) was also a librarian whose experience of assisting pupils to carry out searches for information in a variety of subject areas served to highlight the

importance of *teaching pupils to define appropriate search terms* and to refine them, even before using a computer. She also described the difficulty of ‘ensuring that pupils had internalised and reprocessed information they discovered’ from a pre-selected site since ‘there was a tendency to print out material indiscriminately or... e-mail key site pages to the student’s home computer’ (LL/Rep). She pinpointed the dangers of students’ own lack of awareness of the pertinence of material, as in the case of one struggling low ability student in her lesson:

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 focused on deliberate teaching and reinforcement of generic search strategies which

enabled students to develop as independent, effective, efficient and discerning electronic information gatherers rather than remain as serendipitous and credulous surfer-browsers. (LL/Rep)

She thus addressed an identified need to *develop pupil skills for forming their own ideas, for interpretation, critical analysis and redrafting*. Specific strategies employed by LL included *encouraging processing of information* through note writing and teaching pupils to highlight key points on printouts (as AY did). She also conducted class discussions aimed at getting students to think critically about the nature and source of information retrieved. She considered this to be a generic skill also applicable to book-based work 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 through asking pupils to rephrase electronically derived texts or to formulate bullet points.

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. While pupil skills in this area are now developing, their complexity 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, yet 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, accessibility, reliability and partiality of information on Internet sites. Many teachers tackle the inherent problems through pre-selection of sites containing suitable content, although this raises a tension by undermining the degree of pupil control which a research activity can then offer.

### ***Organising and facilitating peer collaboration***

While it is not unusual to see 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 of the 17 ICT-supported lessons we observed (spanning all subjects involved except Design Technology and Classics). These pupils worked together in (mainly self-selected) pairs on purposefully designed tasks at a single computer towards joint outcomes. They were observed to be discussing and checking suggestions with each other. In six further lessons pupils worked individually, 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.

Teacher accounts indicated that more peer interaction was evident in ICT-supported than in other lessons and in at least five cases, working together was a feature of ICT-supported lessons only. Although three of these teachers remarked that limited computer provision meant that pairwork was necessary, the majority of teachers mentioning collaborative working nevertheless described significant educational and logistical benefits: in particular, physical ease in terms of visibility of joint work and stimulation for generating and exploring (more) ideas. One teacher described how 'working on screen does develop their thinking' through much more discussion being generated in this context, '[bringing] increased understanding and improved learning' (AY).

The role of the teacher in deliberately *facilitating collaboration* at machines – *developing a culture of sharing ideas* – emerged as critical. One teacher was 'trying to bring people together... so they are not just sitting, staring at a screen and working independently' (VM). Another asked pupils to '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 Technology lessons observed, the teachers consciously encouraged peer tutoring:

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)

*Orchestrating* pair composition and *supporting the peer interaction* were also part of the teacher's role, for example ensuring that sufficient technical expertise was present in each group 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).

## CONCLUSIONS

The introduction of ICT can act as a catalyst in stimulating teachers and pupils to work in new ways. These are characterised by teacher-pupil and peer discussion; exploration, analysis and reflection; probing, assistance and feedback. They capitalise on the visibility of work on the computer screen, as pupils exploit the informal opportunities arising to solicit help and feedback, while teachers assess progress and understanding and adjust their support contingently. As pupils' roles become more autonomous, teachers feel that they should encourage and support pupils in acting and thinking independently. Rather than devolving the responsibility for learning either to the computer or to pupils, this means strategically balancing freedom of choice, pupil responsibility and self-regulated learning with structured activity, focused enquiry and proactive teacher guidance.

### *Circumventing emerging constraints on subject learning*

The integration of ICT can introduce a set of new constraints. First, using sophisticated new technology can evidently add an obstructive extra layer of obliqueness or distraction, so that classroom activity needs to be structured in ways which *maintain pupils' focus on subject learning*. However, ICT also offers unique opportunities such as creative manipulation of text or graphic images or electronic annotation. About half of the participating teachers devised deliberate strategies aimed at focusing on subject content through either taming the technology or exploiting the new opportunities arising. Another form of focusing was the perceived need to *structure Internet research activity* to some degree; completely open-ended searching can prove fruitless yet a degree of choice is motivating to pupils, so strategies such as offering some choice within a pre-selected range of sites can provide a compromise.

Secondly (and related to the above), while some uses of ICT (e.g. writing templates or electronic annotation) can act as a prop which will ultimately be removed, in our case studies it was more prominently the use of non-digital tools and resources which was intended to provide additional support in settings where a wholly electronic environment might be impoverished or unrealistic. For example, teachers found it helpful to *support learning and revision away from the technology* by making available printed records and other resources.

### ***Future directions for technology-integrated pedagogy***

The classroom practice of the teachers participating in our case studies could be construed as undergoing a perceptible but “gradual process of pedagogical evolution”. This involved them in development, trialling and refinement of successful activities and strategies, and critical reflection upon their underlying aims and principles. While the teachers were clearly building and elaborating upon established practice in some ways throughout this process, the subject specialists who scrutinised the data for us indicated that the potential of ICT was not always fully exploited within the lessons observed. They identified 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 and some were inexperienced in using ICT in the classroom. It may be that teachers need to take a step back before they can progress in this arena, where in one sense they become novice practitioners again.

A specific example is that teachers acknowledged that *developing new pupil skills for information finding, selection and critical analysis* was necessary in order to harness the vast range of digital information resources now available, whilst safeguarding the accessibility and utility to students of research outputs. However, learners require support for this and the diverse strategies in evidence for encouraging information processing were not pervasive across the sample. Teachers might draw on the practical activities now available to accompany the Key Stage 3 National Strategy for teaching ICT which help pupils to distinguish between fact and opinion and to evaluate validity, reliability, bias, clarity and accessibility. Similarly, there appears to be more demand for *organising, managing and supporting peer collaboration* in the context of technology-supported learning. The teacher’s critical role in this context may include *developing a stronger culture of sharing ideas, reflections and procedures* – with working partners and during *whole class interactive teaching*. The latter may be particularly beneficial in compensating for the physical difficulties faced in interacting with students in a computer suite and was believed to help develop deep levels of understanding. However its role currently appears to be under-developed in the context of ICT use (in part perhaps due to unpredictable technologies affecting lesson pace), and teachers recognised this. In some areas, then, there was a perceived need for actually increasing focus on certain aspects of established practice (e.g. whole class discussion and modeling complex techniques). Access to interactive forms of projection technology is rapidly increasing in schools now, offering the potential to greatly facilitate modeling and mimicry.

Finally, the informal interaction we observed could provide a fruitful starting point for *formative assessment of ICT-supported learning*. This involves two-way feedback between student and teacher that both elicits evidence about where the pupil is and modifies the teaching and learning accordingly. Assessment might capitalise on the greater accessibility of children’s thinking and understanding arising through discussion, interpretation and evaluation when interactive technologies are used – a different level of understanding to the ‘academic’ understanding measured through formal assessment. In sum, the new forms of teaching and learning emerging

indicate that assessment frameworks themselves need to change. Teachers are beginning to consider their role here but external constraints (national tests in particular) currently limit the scope for change.

### *Concluding remarks*

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

Further implications for implementing national educational policy – whose emphasis is now firmly on 'embedding' ICT within subject practice – include teacher involvement in this process. Taking the unusual step of engaging teachers in discussions about pedagogy may encourage them to clarify and re-examine their views in the light of using technology. Distilling and sharing pedagogic expertise concerning ICT use in subject teaching and learning is also critical for change and that is the focus of our recent research with 'expert' practitioners (in mathematics and science), which builds on the findings reported here.

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<sup>i</sup> 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.

<sup>ii</sup> Most participants were in receipt of Best Practice Research Scholarships [BPRS] awarded by the national Department for Education and Skills (DfES); a small number were supported by equivalent grants from the Wallenberg Research Centre for Educational Improvement in the University Faculty of Education.