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Teachers' developing 'practical theories' of the contribution of information and communication technologies to subject teaching and learning: an analysis of cases from English secondary schools

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Teachers' developing 'practical theories' of the contribution of information and communication technologies to subject teaching and learning:
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Abstract
This paper examines teachers' 'practical theories' concerning the contribution of ICT to teaching and learning, as they are elaborated and refined in action. The study arose from a collaborative programme of ten small-scale projects through which participating teacher-researchers aimed to develop a range of pedagogic strategies involving the use of computer-based information and communication technologies (ICT) within their subject areas (Classics, English, Geography, History, Science and Design Technology).

Within- and cross-case analyses drew on multiple sources of data and characterised teachers' initial statements of practical theory in terms of five key themes: broadening classroom resources and reference; enhancing working processes and products; fostering more independent pupil activity; mediating subject thinking and learning; and improving pupil motivation towards lessons. Three cases are presented to illustrate how teachers developed their ideas in action, and issues that prompted teachers across cases to adapt their approaches are discussed.

1. Background to the study

This study examines the 'practical theories' elaborated by teachers working to incorporate use of computer-based information and communication technologies into their classroom pedagogy. Integrating use of such technologies into school processes of teaching and learning continues to exercise educational policy-makers and practitioners. The rationales guiding such innovation remain largely speculative, while the policies framing it are often slender in substance and exhortatory in tone. Moreover, the popular discourse surrounding technology integration appears to neglect the limitations of characterising teaching in terms of the use of specific resources or standard methods. By contrast, as the complexity of what teachers and pupils actually do in classrooms has become increasingly clear, so has the need to explore how participants themselves construe classroom activity. As Brown & McIntyre (1993) argue, the practicable development of pedagogy calls for better understanding of how teachers perceive and think about what they do in their classrooms.

A similar message emerges from studies which have examined the relationship between teachers' adoption of new technologies and shifts in their classroom practice. Kerr (1991) suggests that teachers' incorporation of technology into their practice is one strand in 'a measured development in their thinking about instruction, their role as teachers, and… the look and feel of classrooms as the arenas where education takes place' (p. 132). Other studies have highlighted how teachers' prior practices and routines influence computer use in powerful ways (Miller & Olson, 1994), and have found that the ways in which teachers integrate computers into their classroom practice are strongly mediated by their beliefs about learners, about what constitutes 'good teaching', and about the role of technology in students' lives (Windschitl & Sahl, 2002). Likewise, in a recent review of research literature concerning ICT and pedagogy, Cox and her colleagues (2003) suggest that 'the beliefs which teachers have about the power and scope of ICT, its new modes of knowledge representation and therefore the different ways in which pupils learn, will profoundly affect the affordances controlling the learning actions and activities.' (p.27).

The UK National Grid for Learning initiative in 1998 heralded unprecedented levels of government spending on provision of computer equipment, broadband internet access and on-line resources for schools (DfES, 2003). The official view of ICT as potentially transformative of education has placed it at the centre of the national agenda for school reform. Yet despite substantial programmes of continuing professional development (such as ICT training schemes supported by the New Opportunities Fund to which over 80% of UK schools subscribed), relatively few teachers are 'confidently, successfully and routinely exploiting ICT' within their classrooms (ibid).

Recent American studies have investigated technology integration by teachers caught between 'neoprogressive visions and organizational realities' (Cuban, 1989). Drawing on a nationwide questionnaire survey of a broad and carefully structured sample of US teachers, Becker (2000) concludes that while computers have enabled a minority of teachers to put into practice a more student-centred pedagogy better attuned to their teaching philosophy, they have *not* transformed the teaching practices of a majority of teachers, particularly teachers of secondary academic subjects. Likewise, in a study of two high schools with reputations for technology integration, Cuban, Kirkpatrick and Peck (2001) found that most teachers had adapted technology to fit familiar instructional practices, with only a minority reporting that they had modified their practice in major ways.

Our own recent work has examined what teachers of core subjects in English secondary schools see as successful use of such technologies to support classroom teaching and learning. These teachers pointed to several major types of contribution of technology use: in enhancing the variety and appeal of classroom activity; in effecting working processes, improving productivity; and enhancing presentation; in supporting processes of checking, trialling and refinement; in focusing attention on overarching issues and accentuating important features; in

broadening the reference and increasing the currency of classroom activity; in overcoming pupil difficulties and building assurance; and in fostering pupil independence and peer support (Ruthven, Hennessy & Brindley, 2004). Further examination of these themes showed how professional thinking about technology use is anchored in well-established representations of pupil motivation and classroom learning, and how contrasting subject profiles reflect corresponding differences in wider subject cultures. These findings resonate with those of the InterActive Education research team who noted how practitioners' perceptions of technology use were conditioned by the pervasive subject culture – as well as being influenced by the individual's 'prevailing pedagogical style and personal theories' (John & Baggott La Velle, 2004, p.322).

2. Context and rationale of the study

Our earlier study drew on focus-group interviews in which subject departments outlined and discussed examples of what they considered to be successful practice. These discussions formed part of the formative phase of a programme of research undertaken with a group of secondary schools involved in a research partnership with our university faculty. This programme had been initiated to address the use of ICT to support teaching and learning, identified as an area of mutual interest and priority across the partnership. In the subsequent developmental phase reported here, volunteer teacher-researchers undertook small-scale, school-based projects in which they investigated self-devised, technology-integrated pedagogical strategies in their own classrooms. These projects were supported by Best Practice Research Scholarships funded by the Department for Education and Skills. Although the projects all built to some degree on classroom approaches already employed by the teachers, they typically involved significant development of the use of computer-based tools and resources within these approaches. Taking this opportunity to investigate pedagogical practice, not just in action, but in the course of development, the study reported here examines all ten classroom-focused projects in the programme (as summarised in Table 1).

<Insert Table 1 about here>

The forms of technology integration addressed by these projects were of three broad types. Projects in Classics, Geography, History and Science (five in all) sought to develop *internet-resourced learning*. Projects in English (three in all) focused on *text reversioning*, employing word-processing tools to rearrange texts in order to explore form, content and genre. Projects in Design Technology (two in all) explored *virtual construction*, using specialist software packages to enable pupils to design systems or objects on screen.

Teacher-researchers participating in the programme worked on their project singly or with a colleague from the same department. Participants met in larger cross-project groups on six occasions over the course of the 2000/01 school year. The main function of these meetings was to support the planning and reporting of projects through discussion in cognate groups and consultation with the university team associated with the programme (to which we belonged). In the early stages of the programme, each project developed an outline plan. During the period when classroom work associated with the projects was taking place, each participant was visited in school by a member of the university team. One element of the visit was a standard sequence of lesson observation and ensuing teacher interview, intended to contribute both to the project in progress and to subsequent analysis by the university team. After the close of the school year, project reports were prepared, for final submission in the particular format required by the funding agency.

Practical theory

An organising idea proposed by the university team was that of a *practical theory,* taken – for the purposes of the project – as some form of orienting statement concerning how a technology is seen as supporting learning, and guiding the development of a pedagogical strategy incorporating its classroom use. This use of the term 'practical theory' to refer to an explicit model of practice – or one capable of articulation – follows some previous usages in the literature (Kroath, 1989; McIntyre, 1995) but differs from others which have used the term in a sense closer to ideas of 'implicit theory' and 'practical knowledge' which emphasise the tacit, personal and situated facets of teacher cognition (Clark & Peterson, 1986; Marton, 1995; Munby, Russell & Martin, 2001).

As we had anticipated, researching their development of classroom practice was a new experience for many of the participating teachers, and they tended to find it easier to plan actual classroom activities than to characterise these in terms of key pedagogical ideas. In effect, we employed the term 'practical theory' as a tool to highlight a central element of the proposed research process, seeking to make this element manifest and significant to our teacher colleagues; that of generating as explicit as possible a formulation of key ideas ('practical theory' in our chosen sense of the term) from what might otherwise have remained implicit (in the other sense of 'practical theory' found in the literature).

In introducing the idea of a practical theory to the teacher-researchers, material from our earlier study was used to sketch the ideas guiding some current practice in the participating schools. A number of processes were suggested as aids to clarifying, elaborating and refining participants' initial statements of practical theory, including reflection on planning decisions and discussion of teaching plans. It was anticipated that these initial statements would subsequently be elaborated and refined in the light of experience and evidence. Accordingly teachers were encouraged to articulate their ideas concerning the contribution of ICT to teaching and learning and to operationalise and evaluate these in practice. Evaluation was strengthened through formal research processes enabling triangulation of data derived from practitioner, peer and pupil perspectives.

3. Design and method of the study

This study, then, sought to identify key elements of teachers' practical theories, and to examine their elaboration, by drawing on data collected over the course of each project. Practical theories were outlined in initial project plans. Teachers' summative conclusions and reflections on their practical theories were sought in their final project reports. Thus, our analyses within and across cases drew upon practitioners' own research plans and reports as well as observation and interview data collected by the university research team.

Lesson observations focused on teachers' and students' roles and ways of working using ICT. Observations were followed directly by a 2-minute interview – inviting teachers' immediate comments on the lesson – and subsequently by an extended, semi-structured, post-lesson interview – intended to stimulate an account, grounded in the observed lesson, of teachers' thinking about their practice and specifically about the role played by ICT. Questions and prompts were designed to elicit teachers' perceptions regarding the contribution of ICT to the success of the lesson and achievement of their lesson aims, to elucidate teacher and pupil strategies and roles observed within the lesson, and to promote teacher reflection on adaptation and development of the approach for future use. Observations and interviews were audiotaped and interviews transcribed; lesson plans, activity sheets, samples of student work and digital photographs provided additional records.

For each case analysis, observation and interview data were collated and summarised; where pairs of teachers worked together, similarities and contrasts of approach were noted.

Summarising sentences were added throughout the transcripts, segmenting the text and highlighting changes in focus of talk. Corroboration of emerging themes was provided by referring back to lesson observations to triangulate the interview data. To minimise bias, counter-examples were sought and data were analysed by two researchers working independently; summaries and conclusions of each case study were reviewed by the original observer, and later by subject specialists within the university.

For the cross-case analysis, interview transcripts were imported into a computer database (QSR NUD*IST) and thematic codes applied in a systematic and recursive process of constant comparison (Glaser & Strauss, 1967). Initial scrutiny of interview transcripts suggested a number of broad themes from which more detailed codes were subsequently derived. Themes and sub-themes were examined across the 10 cases with particular attention to explication of practical theories and instances of practice being adapted or refined.

4. Themes across practical theories

At the outset of their projects teachers found it difficult to articulate in detail their ideas concerning the anticipated pedagogical use of ICT and some of their initial statements of practical theory were somewhat sketchy. Scheduling constraints precluded any iterative development of plans, something that might, in other circumstances, have encouraged more comprehensive accounts. However, scrutiny of initial statements revealed five distinct – but interconnected – themes, relating to the perceived role of ICT in:

Broadening classroom resources and reference
Enhancing working processes and products
Mediating subject thinking and learning
Fostering more independent pupil activity
Improving pupil motivation towards lessons

The distribution of themes across cases is shown in Table I. Our analyses of case data indicated that these five themes remained salient across the developing practices – as elaborated in teachers' interview responses and final reports.

Broadening classroom resources and reference

This theme centred on the idea that technology – notably the internet – would extend the information available within the classroom. It also encompassed more specific ideas relating to the range and currency of such resources, in contrast with limitations of textbook information: for example, highlighting the richness and variety of online materials (History); accessibility of up to date information such as news items and contemporary features (Geography and Science); and availability of a greater range of textual material for analysis (English). It was also envisaged that access to a wider array of resources would open up new possibilities for differentiation through tailoring activities to particular learning needs and interests of individuals or groups (Geography and Science).

Enhancing working processes and products

This theme focused on the idea that ICT would facilitate working processes and/or improve resulting products. For example, teachers drawing on internet resources took the view that technology tools would make research processes quicker and easier (History and Classics) and offer alternative ways of communicating findings and presenting work (History). Similarly, formatting tools would enable pupils to edit, redraft or redraw work more easily (English and

Design Technology) and produce output of better appearance (English, Geography and Design technology). In two cases it was envisaged that technology would overcome physical limitations associated with existing methods, thus not only facilitating pupils' work but also relieving the teacher of related organisational tasks: for example, by accessing news stories online instead of pre-recording videos of news footage (Geography) and utilising simulated circuit-building software instead of distributing sets of physical components (Design Technology).

Mediating subject thinking and learning

Teachers in all projects anticipated that ICT would provide tool-mediated support for subject-related thinking and learning. These ideas went beyond the types of assistance outlined in the previous theme to focus more directly on how use of technology would contribute to furthering pupils' subject knowledge and understanding. In some projects such ideas were expressed only in broad terms: for example that use of ICT would enhance pupils' understanding of geography or appreciation of scientific processes. Elsewhere, more specific ideas were articulated. For example, the history teachers expected that working with a wider range of sources would help pupils to develop empathy and appreciation of different viewpoints. English teachers viewed technology as helping to develop pupils' awareness of format, audience and purpose by providing tools with which they could deconstruct, examine, manipulate and reversion text more easily. In Design Technology, it was suggested that immediate feedback afforded by use of circuit simulation software would encourage pupils to trial ideas and hence increase their understanding of electronic theory and ability to design circuits.

Fostering more independent pupil activity

The desire to utilise technology to induce and support more self-directed pupil activity was widespread. In three projects (Classics, Geography and Science) teachers set out to foster generic study skills – such as the ability to extract and summarise relevant information – through internet research activities. In five projects (all involving use of internet resources) technology was viewed as facilitating less teacher-led approaches and enabling pupils to work more autonomously, for example: by supporting individuals' research efforts through accessibility of materials (History, Geography, Science); affording the freedom to select from sources that are not teacher-determined, in contrast with textbook provision (Geography, English); and enabling a choice of presentation methods through availability of different software tools (History). Likewise, in design technology, employment of simulation software and computer design tools was expected to engender more student-driven patterns of working.

Improving pupil motivation towards lessons

The anticipated role of ICT in improving pupil motivation towards lessons was often closely linked with previous themes. Technology was seen as a vehicle for engaging pupils' interest in subject topics, for example through the interactive and multimodal qualities of computer-based work (Geography, Science, Design Technology). It was thought that immediacy of access to resources and relevance of materials would render learning more enjoyable for pupils (Classics, English, Geography). Reduced handwriting requirements and higher quality presentation were also seen as motivating, the latter likely to increase pupils' self-esteem (Design Technology).

5. Practical theories: examples from three cases

Three examples have been chosen to illustrate the practical theories of technology integration of projects of each type (internet-resourced learning, text reversioning, and virtual construction).

Each practical theory is first sketched in the original terms of the participating teachers, and then related to the five overarching themes.

5.1 Use of a virtual archive in History teaching

This project aimed to enhance a History unit by creating a virtual archive of documents and artefacts relating to the First World War. The practical theory of technology integration proposed by the participating teachers had two main components. First, giving pupils access to a wider range of historical sources than had previously been possible was intended to help pupils appreciate different viewpoints and develop empathetic understanding. Second, using ICT tools in working with this material was expected to support pupils' developing skills of analysis and communication, by facilitating organisation of ideas and permitting new forms of presentation. In later interviews, teachers expanded on both these ideas.

By selecting from the considerable material available on the internet, the teachers had assembled a rich range of resources:

> When we looked at… war propaganda posters, there's a site which simply doesn't exist in book form or any other form, where you've got posters from Canada, America, Britain, France, and being able to research that [was] fantastic. [OL/Int]

> We base our trip around the Vimy Ridge site, but if you go looking for information in textbooks about the Battle of Vimy Ridge, you won't find any... [and] of course fieldwork needs backing up... with other sources. [AY/Int]

Use of different media and varied sources was intended to promote multisensory and empathetic understanding:

> We've got the… ability for kids to use their eyes… to get a feel of the environment that the soldiers were fighting in…All those things, they're alerting the different senses what it was all about. Perhaps we're getting a more… total picture. [AY/Int]

In a lesson in which pupils visited a virtual exhibition of First World War paintings, they were asked to 'think about how artists could contribute to our understanding of what was going on in the war'. Care was taken to create a sense of authentic contact with a wider world:

> The sense that this was an exhibition that they were visiting, a virtual exhibition, not just some pictures I'd chosen from a book, but something… connected with the UN… I think that was important, to put those pictures into context. It… brought the reality of outside into the classroom… This was something that they could themselves visit… in the same way that they're going out to visit some battlefield sites in France at the end of this month. [OL/Int]

In another lesson, the impending battlefield visit helped to create a sense of import and urgency:

> On Friday we're going to Vimy Ridge, so we're still trying to get this notion of how far this is a Canadian victory because we've got other information which tells us it wasn't just… Also, we've just located some information about one of the guys who's responsible for quite a few of the sites that we've looked at… so how reliable is he as a source? [AY/Int]

Both teachers also expanded on the use of ICT tools to interact with materials, analyse evidence, and present ideas. Reviewing how pupils had prepared their reports on the virtual exhibition, the teacher commented on several features:

> The ability to manipulate the pictures was important. I mean simply enlarging…to home in on details…that was important... The sheer variety of ways of presenting ... would not have been possible without the computers. The actual copying and pasting the picture, placing it, all helps with the discussion. [OL/Int]

He pointed to greater emphasis on discriminating analysis which had proved motivating to pupils:

> 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. So a lot more copying and pasting selectively. Which I think has helped... to motivate them. [OL/Int]

Likewise, his colleague identified new ways in which pupils worked with electronic materials:

> You can almost use the computer like a notepad, whereas when kids are working… with a written document… we don't let them scrawl all over it because we need to use it again… This… working on screen does develop their thinking, because there's been a lot more discussion generated. [AY/Int]

The teachers emphasised how the use of ICT tools supported analysis and argument:

> Sorting through the data, classifying and supporting arguments with evidence were all facilitated by the use of ICT. Creating tables helped pupils to classify their ideas and allowed them to manipulate what they found more easily. [AY&OL/Rep]

They also pointed to related changes in pedagogical interaction which they had not anticipated:

> We both found it was easier to intervene as there was already ongoing dialogue between the pupils. Having work on the screen enabled both pupils and ourselves to view and discuss the work collaboratively. This contrasts with our previous classroom experience with these groups where it is often difficult to do this. On a number of occasions pupils discovered sources which we had not seen. This happens rarely when students do not have access to the range of information available, and led to the teacher and pupil unravelling the sources together. [AY&OL/Rep]

In this case, then, teachers had drawn on the wide range of internet material available to *broaden classroom resources and reference;* indeed the richness of this material had prompted teachers to devise new activities. They reported that use of ICT tools *enhanced working processes and products*, enabling pupils to access and organise material more easily, to examine and annotate it in new ways, and to enhance presentation. Such use of technology contributed to *mediating subject thinking and learning,* as engagement with diverse sources facilitated pupils' appreciation of different perspectives on historical events, and new ways of working with such material supported critical thinking, allowing pupils to 'support findings in a more sophisticated way'. Whilst they were keen to *foster more independent pupil activity*, both teachers found that their early lessons had been too 'open' and they needed to achieve a balance between 'giving a clear focus but allowing pupils freedom to communicate in whichever way they wanted to'. While *improving pupil motivation towards lessons* was not a primary consideration for these teachers, they noted that pupils enjoyed, and were motivated by, more critical engagement with materials and reduced writing requirements.

5.2 Use of text reversioning in English

This project focused on the use of ICT-supported text reversioning to explore form, content and genre. The participating teachers' practical theory centred on the idea that using a word-processor to assist the (re)organisation and (re)presentation of poetic texts would improve pupils' capacity to analyse them and to identify 'techniques by which writers persuade and affect' [LR&RE/Rep]. They also saw the internet as giving access to a broader range of digital texts to support this work.

In one lesson, pupils worked on the text of a ballad. Their task was to identify instances of alliteration and assonance, to highlight these in contrasting colours, and to insert textbox annotations explaining the effect of these poetic techniques. The teacher regarded ICT tools as greatly facilitating the revision required in such exploration:

> The whole business of being able to highlight things in colour, change your mind, go back, which you couldn't do on paper, was useful for this task. Coming to creating text boxes and things, again you can redraft and make nice clean copies on the screen, when on paper you'd have crossings out. [LR/Int]

Electronic text was seen as more manipulable than printed script, and the screen as a metaphorical lens:

> You are scrutinising little bits of text for quite a long time, and you're doing something with them. I think you've got the whole business of mobilising the text a bit, maybe making it bigger or moving it up or down, so it's clear, particularly when you've got collaborative

> work…you're both looking at the same thing, so it's a bit like looking through a magnifying glass... what the program allows you to do is play around with the text in a very visible way. [LR/Int]

In another lesson, pupils divided a Shakespearian sonnet into sections and highlighted rhyming words by altering their font style. They were encouraged to discuss their work and read the poem aloud to check rhyming connections between the sections they had already distinguished. RE commented on how ICT supported pupils' thoughtful engagement with the material:

> Once they'd divided it up, they'd concentrated and focused, then the meaning became clear…It sort of unfolded in their minds and they were able to express that unfolding…on the screen, so in that respect I thought it was wonderful and I don't think they would have been able to reflect that in writing on paper. [RE/Int]

Both teachers suggested that the striking visual presentation afforded by ICT could enhance grasp of poetic sequence and pattern:

> Just looking at that example there, the balance of the blue and pink, [and so] obviously in that poem you can see he's used both techniques a lot… I think it probably makes you read it differently because the whole word is in colour. You know, you're actually re-reading it because it looks… a different way, and you wouldn't get quite that same effect with underlining. [LR/Int]

The teachers also saw pupils' enjoyment of learning activities as being heightened by using ICT – in no small part due to its function in allowing pupils to create well-presented work:

> You could do [the activity] by…arranging different pieces of paper and cutting it out, but it's not as clean…it doesn't look as good, and given that students…are obsessed with not showing corrections … it's perfect for that. [RE/Int]

One also remarked that although these activities could have been carried out by more traditional means, the inherently motivational qualities of ICT gave a fillip to his subject lessons:

> It doesn't matter if you could do the same thing using paper. The point is that these students…like using [computers]… and so it can reactivate lessons that would otherwise be a bit tired. [RE/Int]

Reflecting on the extent to which technology had contributed to the achievement of their objectives, the teachers underlined the importance of matching approaches to specific learning aims. Whilst recognising the merit of ICT in assisting initial – and relatively rapid – deconstruction of text – they considered that students' fuller appreciation of language and meaning had been promoted through wider classroom discussion. In an interesting refinement of their practical theory the teachers had come to view technology as supporting one type of activity but inhibiting another:

> We both discovered that it was only in the traditional whole class discussions, as an adjunct to work in the ICT lab, that the level of deep understanding and appreciation we hoped for was achieved. We feel that it is the very provisionality and speed of ICT that inhibits the natural gestation and growth of ideas that one witnesses in the ordinary classroom dynamic [LR&RE/Rep]

As their initial practical theory suggested, teachers found that using the Internet *broadened classroom resources and reference* not only by giving access to digital material for the class to work with, but providing a variety of versions from which to choose. Similarly, *working processes and products were enhanced* as electronic text was easier to manipulate, format and edit. Presentation was often of higher quality than handwritten versions. Teachers aimed to *mediate subject thinking and learning* by using technology to increase pupils' capacity for examining texts. However, they observed that whilst highlighting and moving text around could help pupils to focus on poetic techniques, not all pupils had the level of technical expertise needed to manipulate the tools successfully. Furthermore, they noted that overusing text effects could result in confusion rather than clarity.

Tasks were designed to *foster more independent pupil activity* and encourage exploration of text, but although technology enabled effective mechanical analysis, teacher intervention and

whole class discussion were seen as crucial in promoting pupils' deeper appreciation of language and meaning of the verse. As in the first case study, the teachers became concerned with providing appropriate structure and direction. This had led one to develop new strategies: for example, applying passwords to worksheet hyperlinks, thus creating automatic teacher checkpoints that allowed him to monitor individuals' progress.

As in the previous case*, improving pupil motivation towards lessons* was not explicit in these teachers' original practical theory, but motivational effects were noted in practice; teachers attributed these effects to the novelty and popularity of computer use and the ease of correction afforded by ICT. However, their report also noted that 'apparent engagement was not necessarily indicative of learning'.

5.3. Use of a circuit simulator in Design Technology

This project aimed to exploit simulation software in teaching about electronic circuits. The guiding practical theory had three main elements: first, that working with virtual components would circumvent physical constraints and hazards associated with traditional circuit-building apparatus; second, that pupils' understanding of theoretical aspects would be enhanced by the processes of designing and manipulating on-screen circuits with immediate feedback enabling them to trial ideas and see the results; and third, that pupil motivation to use ICT would increase their engagement with the topic.

On the first point, reviewing a lesson in which pupils constructed and tested simulated circuits, the teacher highlighted how, without physical apparatus to manage, his time was freed to target pupil support where it was needed.

> It makes the management of the lesson so much easier and therefore I can spend more time dealing with their enquiries and understanding, rather than being a storekeeper… giving out materials, getting back materials, chasing up who's dropped the lightbulb [KE/Int1]

Touching on the second element in discussing this same lesson, the teacher suggested that by seeing the effects of connecting components inappropriately, pupils could recognise and rectify their own mistakes in a way that would not be possible using hand-drawn diagrams:

> It enables them to… see what happens if you connect things up the wrong way…Whereas if you draw it on a piece of paper, the pupils wouldn't have known whether they'd got the circuit right or not … it would then be reliant on me going round saying [so]… It enables them to make mistakes and learn from it. [KE/Int1]

Reviewing a later lesson, the teacher elaborated this view in describing how virtual construction enabled less able pupils to progress by 'discovering what something does empirically, rather than having to understand its function':

> [The pupil] doesn't need to know that OR means it's this and this, he can just sit and press a button and see what happens and write down the response… For some of the more complex functions where he can't trace the sequence of events, where you've got several logic gates joined together, he can still see what it does, even if he can't understand how it gets there. [KE/Int2]

On the third element, the teacher noted how such activity contributed to pupils' engagement:

> I think that they engaged in it much, much more readily than an equivalent paper-based activity.… Because they were able to use the simulation package and drag things around, and because those components would actually blow up in simulation. [KE/Int1]

Equally, in drafting their own notes on the work undertaken, pupils could copy the screen diagrams of circuits into a word processor. The teacher emphasised how the facility to present work attractively was especially motivating for pupils who would have struggled to produce handwritten material:

> It makes more of a level playing field in terms of producing good notes for some of the less able because they're often not able to present their work well and to produce anything that

> looks half-decent…For them to be able to produce notes that look good, even if they're not terribly complex, or full, is good for the esteem. [KE/Int2]

In the later interview, the teacher also drew attention to the way in which software enabled pupils to work more independently, allowing some to advance beyond the limitations of available teacher expertise:

> The most able students were … working at their own level, and they were able to progress further than I would get them if I were teaching without that program. They learnt things that I would find very difficult to teach at the moment because of my lack of expertise in that area. [Pl/Int2]

Whilst affirming all of these ideas, the project report also pointed to the value of incorporating complementary approaches to support development of pupil understanding:

> Although the software is a powerful tool, in this project teaching was found to be most effective when several approaches were combined. To that end, there were practical design-and-make lessons running alongside the theory lessons. In the theory lessons, as well as didactic input at the start of each session and individual support, students were also given printed notes. These often had questions on and were used as homework tasks. This made it possible for the teacher to assess the level of learning that was taking place. [KE/Rep]

The role of ICT in *broadening classroom resources and reference* did not figure in this teacher's original theory, but one unanticipated benefit of using the chosen software was that its tutorial provided material that allowed some students to progress beyond the teacher's current expertise. For the teacher, working with simulated – rather than physical – circuits facilitated management of the lesson; for pupils, constructing, copying and pasting circuit diagrams into word-processed notes *enhanced working processes and products.* In addition, the technology contributed to *mediating subject thinking and learning* by enabling pupils to see the effects of connecting components in different ways, allowing them 'to make mistakes and learn from it'. Nevertheless, KE suggested that the most effective teaching and learning strategy was one in which theory-oriented simulation activity was complemented by practical 'design and make' sessions.

The series of lessons was planned to capitalise on technology's perceived role in *fostering more independent pupil activity* and the teacher observed how dynamic visual feedback on-screen lessened pupil dependency on their teacher to confirm or correct their actions. However, he found that it was important to monitor pupils' notes in order to identify and deal with learning gaps. Along with other teachers, KE noted how use of ICT contributed to *improving pupil motivation towards lessons,* particularly for less academically successful pupils who were able to produce better-looking notes; but he also became alert to the possibility that pupils were simply producing 'neat nonsense'.

6. Development of practical theories

During the course of their projects, and in their concluding reports, teachers endorsed many of their initial conceptions about the contribution of ICT to classroom activity. Across cases, however, classroom experience also prompted the review and development of earlier ideas.

Broadening classroom resources and reference

Several teachers described how the internet had furnished new materials that brought 'the reality of outside' into the classroom; for example, online collections of war posters and paintings (History), illustrations of Roman artefacts being offered for sale in an online auction (Classics) and 'wonderful, glowing pictures' capturing the topography and culture of the country being studied (Geography). Nevertheless, across cases, finding suitable materials often turned out to be unexpectedly problematic for both teachers and pupils. It was reported that where pupils were tasked with searching out information for themselves, time was wasted 'ploughing

through' search engine results because when relevant sites were found, the material they contained was frequently pitched at too high a level. Particular problems were posed for a class of lower-attaining pupils who became distracted by banners offering other services and 'hopelessly lost' trying to find the information they needed. Several teachers remarked how students required 'more intervention' to enable them to discern and extract relevant information from online sources than would have been the case in textbook-based lessons.

In response to such difficulties, teachers developed a range of guiding strategies such as offering pre-defined search terms, preparing a portal page with hyperlinks to pre-selected sites or making suitable sites available over the school intranet (see Ruthven, Hennessy & Deaney, 2005; Hennessy, Deaney & Ruthven, 2005). However, the process of locating relevant websites that were pitched appropriately for pupil needs was found to be highly time-consuming. Nevertheless, having such a variety of internet resources available at no additional cost was seen as a 'real bonus' which offset the time needed for development.

Enhancing working processes and products

There were many instances where teachers felt that use of computer tools had enabled material to be collated, drafted, edited and manipulated more easily, and presented to a higher standard. However, in cases where teachers had envisaged that using the internet would make research processes quicker and easier, some reservations emerged, as indicated in the preceding section. It was also reported that some pupils had difficulty reading web page text because of small font size, long sentences, complex vocabulary and the presence of strongly coloured or patterned backgrounds; one teacher of a lower-attaining class devised re-formatting techniques for simplifying the layout and appearance of such texts.

Whilst use of computer tools enabled pupils to improve the presentation of their work, it was noted that some individuals became more preoccupied with appearance than with content and that 'technical virtuosity' did not always equate with 'insightful' work. Issues concerning the diversity of pupils' technical expertise also emerged elsewhere. All but one of the projects utilised generic software packages and at the outset there was a prevalent assumption that pupils would bring a good level of ICT skills to their subject lessons. The teachers anticipated that explicit teaching of ICT as a discrete curricular subject, accompanied by increased home use of computers, would have provided pupils with such capabilities. As projects progressed, however, several teachers noted an 'uneven skill base' and this affected both the pace of their lessons and the progress of individuals. The anticipated benefits of ICT were found to be largely dependent upon pupils possessing, or acquiring, the operational skills necessary to use it effectively. Across projects, teachers discovered that they needed to be familiar with individuals' technical as well as subject abilities, and to build in commensurate strategies for supporting skill development; indeed, improvement of pupils' ICT skills was subsequently widely reported as a positive outcome of project activities.

In the two design technology cases, where projects employed specific subject-related software packages, directed ICT skills teaching was a planned part of the lesson series. However, it was noted that learning new software skills could initially add complexity to given tasks, and that some pupils preferred using manual methods; for example, pupils producing orthographic drawings by hand were said to have a 'head start' as a consequence of their existing dexterity in using pencils and rulers, whilst further support was needed for the group using computer-aided design tools.

Mediating subject thinking and learning

In many cases, initial ideas that technology would enhance or support subject activity were corroborated through practice: for instance, in an English class, the ability to handle large amounts of text more easily was seen to have resulted in pupils producing a 'higher quality of re-

casting' than achieved in paper-based exercises. Whilst reports were often focused on ICT providing alternative, more efficient, or attractive ways of working, there were also instances where technology was perceived as having been instrumental in mediating shifts in subject reasoning. In particular, where teaching aims included encouraging development of pupils' analytical thinking, ICT tools were seen as allowing source material to be segmented, mobilised, manipulated and annotated in ways that 'would not have been possible' without computers. For example, it was reported that pupils were thus able to examine English texts in a 'more precise' way and to pursue 'new paths to thinking' about their contents – and to 'home in' on details of images, tabulate, re-organise and utilise material to support argument in a 'more sophisticated' way in History. Interactivity and the immediate visual feedback afforded by use of technology were seen as playing important parts in these processes. Similarly, in Design Technology classes involving construction of virtual objects or systems, teachers viewed such feedback as having contributed to pupils' deepening conceptual understanding, enabling them to 'see... quite clearly that it's not right' and to 'suss it out for themselves'.

It was noted that these interactive ways of working not only prompted pupils towards 'thinking more' but also stimulated productive discussions between them, though teachers also commented on the importance of their own role in being on hand to question, prompt, explain and guide as needed.

Fostering more independent pupil activity

At the outset nearly all the teachers had envisaged ICT-based activities in which students would find their own resources or create their own pathways of learning. As described in an earlier section, difficulties in locating appropriately-pitched material and issues of time management prompted some teachers to revise their approaches and adopt more directive strategies. The difficulties posed by an open-ended approach were most often identified in projects making major use of the internet. Tensions also emerged between encouraging more autonomous, self-paced, exploratory activity and ensuring that pupils' attention was drawn to salient elements of the topic in hand.

Many concluded that, to be successful within the classroom, information-seeking activities should be very clearly structured and focused (Ruthven et al., 2005; Hennessy et al., 2005). Some identified specific sites prior to the lesson and directed pupils towards them. However, limiting parameters of choice greatly curtailed opportunities for pupils to acquire and practice effective search techniques. Consequently, other teachers developed a collection of pre-filtered sites from which pupils could select their own material – thus retaining an element of choice, and a degree of searching.

Providing effective guidance and support without stifling creativity emerged as another concern. This called for a balance between offering learners more security but risking similar task outcomes, and providing opportunities for greater independence but risking pupil confusion about task requirements. The need for provision of, and support for, differentiated tasks also became apparent to many of the teachers (for example, enabling higher ability pupils to 'fly a little bit' or giving more step-by-step instructions to the less able to 'keep them on board'), though few actually implemented these approaches fully during their projects. Indeed, whilst many teachers had originally perceived ICT as affording support for more student-centred approaches, the pragmatics of managing this style of working led the majority to devise more regulated and structured tasks.

Improving pupil motivation towards lessons

Initially cited in six cases as a key component of their practical theory, the motivational affordances of ICT were underlined by every teacher during the course of their projects. Teachers variously associated improved motivation and engagement with immediate access to

relevant resources, alternative approaches to classroom work and reduced handwriting requirements. Pupils' self-esteem was reported as enhanced by production of well-presented work and a sense of change, privilege, and enjoyment engendered by using the technology. Whilst it was acknowledged that similar learning outcomes might have been achieved by adopting other methods, the enjoyment pupils derived from using computers was viewed as inherently motivational – and sometimes catalytic in promoting their engagement with subject material. The interactive qualities of ICT-based tasks were seen as encouraging pupils to become 'active, rather than passive, learners'. Nevertheless, some teachers also noted 'a fashionable buzz factor' about ICT lessons which lent them an 'air of pupil engagement' whether or not learning was being moved on through work.

It was often reported that pupils exhibited improved behaviour in computer lessons, but there were signs that when novelty value faded, levels of engagement diminished. Levels of engagement were also seen to fluctuate with different types of activity. For example, one teacher noted that whilst most pupils remained on-task during exploratory, creative tasks, those of lower subject ability became bored when lessons involved mainly reading tutorial material on screen. Across cases teachers became aware of the need to configure tasks carefully and to adopt more proactive and responsive strategies during computer-based lessons in order to promote and maintain students' engagement with the task in hand, rather than relying solely upon the technology itself to do so (Hennessy et al., 2005).

Emergent features and shifting patterns of classroom activity

All but three of the teachers noted how co-opting technology into the milieu of classroom activity had presented additional management issues in terms of dealing with lesson re-location, limited access to machines, confined room layouts, system unreliability and lack of technical support. Whilst some of these adversities had not been entirely unanticipated, the need to 'have something up your sleeve as a back-up' became highly salient, and strategies for surmounting or circumventing such difficulties more finely honed.

Although not prominent in teachers' initial statements of practical theory, the significance of the teacher's role in orchestrating and mediating ICT-based activity emerged strongly in relation to each of the five themes (as outlined in preceding sections) and was highlighted by every teacher over the course of the projects: for example, in locating appropriate materials and guiding pupils towards them; structuring tasks to harness ICT tools effectively in meeting curriculum objectives; supporting pupils' use of technology; encouraging more autonomous approaches; furthering development of subject understanding through supportive pedagogical strategies and monitoring progress (Hennessy et al., 2005).

Across cases there were also indications that incorporating computer-based activities had evoked subtle changes in the dynamics of classroom interaction and pedagogic practices. The most widespread shift reflected the pattern of computer-oriented classroom organization in which pupil attention was redistributed away from a central teaching position. For example, teachers spoke of becoming 'far less didactic' and 'spending more time with individuals and pairs' and commented that they found it 'easier to intervene as there was already ongoing dialogue between pupils'. In three cases group size necessitated sharing of computers and pupils worked in pairs, but, across cases, teachers' accounts indicated that more peer interaction took place in ICT-supported than in other lessons; indeed, genuine collaborative activity was seen in 10 of the 17 lessons we observed. Furthermore, as noted earlier, it was claimed that the discursive activity engendered by this style of working brought 'increased understanding and improved learning'.

On the other hand, some teachers suggested that, notwithstanding the beneficial features of distributed ICT-based classroom activity, there remained a significant role for whole-class, teacher-led discussion as part of an effective teaching strategy. Likewise, it was reported that

teaching had been most effective when 'several approaches were combined'. Indeed, across cases, there were signs of evolving hybrid practices involving a conjunction of resources and methods and these are reported elsewhere (Hennessy et al., 2005).

7. Discussion

Our concern in this paper has been to achieve a better understanding of teacher thinking about integrating use of computer-based tools and resources into subject teaching and learning in the secondary school. While covering a broader range of subjects than our earlier work (Ruthven et al., 2004), teachers in this study initially nominated broadly similar affordances of technology in supporting classroom activity and learning in their subject areas. Initial theories concerning the anticipated contribution of ICT had been to some extent conjectural since most of these teachers had limited experience of using technology within their classrooms. It was striking that whereas their early ideas highlighted the affordances of technology, often expressed by according agency to the technology in enhancing classroom work, the teachers' strategic role in structuring tasks and activities emerged as key in harnessing ICT to provide appropriate focus on topics and concepts, orchestrate fruitful learning opportunities, and support the development of effective data handling skills and techniques.

The preceding examples and findings show how elements of teachers' initial theories were modified in the light of 'new data on classroom reality' (Kroath, op cit); subsequent adaptations of practice tended to comprise subtle changes and adjustments that foregrounded the mediating role of the teacher. For example, across cases, teachers encountered tensions between fostering the more student-driven or 'independent' approaches initially perceived to be afforded by using ICT, and providing appropriate levels of structure and direction to support achievement of curricular aims. In this respect, then, they were indeed caught between 'neoprogressive visions and organizational realities' (Cuban, 1989). Nevertheless, these teachers certainly achieved more than simply adapting technology to fit familiar instructional practices and there was some evidence to suggest that new pedagogic approaches were being shaped through the processes of assimilating digital tools and resources to classroom use.

Appropriating the use of technology appeared to be associated with a refashioning of pedagogical activity beyond mere replication of existing practice, though the context and nature of adaptation differed between practitioners. For example, a lack of textbook information on certain topics and a new curriculum requirement to develop skills of scientific enquiry prompted two Science teachers to devise a series of internet-based lessons through which they aimed to promote more active student participation in research activity; they supported this through use of online worksheets containing links to pre-selected sites, whilst encouraging pupils to draw on other book-based materials too. Access to varied sources provided new opportunities for evaluation, analysis and synthesis of information and teachers aimed to develop strategies for furthering pupils' skills in this area.

For the History teachers, the place of analysing and evaluating varied sources was perhaps better established, though use of the internet greatly increased the range available. Their report emphasised the value of collaborative working and detailed how digital tools had been utilised to enhance and extend pupils' ability to interact with, and synthesise material; like the Science teachers, they considered that they had became 'less didactic'.

The two English teachers likewise drew on internet resources to provide additional texts for classroom use and employed digital tools to facilitate their analysis. They created a number of innovative activities, but found working electronically rather than manually required careful re-pacing of lessons to allow for quicker mechanical de-construction of text, but more time for discussion of emerging features. The Design Technology teacher combined practical work, 'didactic input' and computer sessions to support his teaching of electronic theory. Use of virtual

rather than material circuit-building enabled him to enliven an otherwise 'dry' topic; providing tasks that required pupils to work more autonomously 'released' him to help pupils who needed his support. By referring more able pupils to an online tutorial, he enabled them to progress beyond his current expertise.

Skilful teaching can be viewed as an adaptive process which embodies a cycle of (implicit or explicit) pedagogical reasoning (Shulman, 1987) in which factors such as learning goals and objectives, available resources (and their affordances), pupil group characteristics and other situational variants may influence and guide pedagogical action. Sociocultural perspectives (e.g. Wertsch, 1998) emphasise the complex, synergistic relationships between the contexts and practices that both frame and constitute the learning environment, yet it is clear that 'transformation' of the educational domain is not achieved by simply introducing new cultural tools as the rhetoric suggests. Pedagogical innovation remains an important focus of contemporary partnership research initiatives within the field (e.g. Somekh and Pearson, 2004) but attention to teachers' intentions in co-opting use of technological tools is considered critical in understanding the evolutionary processes of their integration into regular classroom practice (Miller and Olson, 1994; Watson, 2001).

Indeed, through relatively small, yet significant adjustments, teachers in our study appeared to be re-calibrating their activities to combine and deploy technological and pupil agencies to support subject teaching and learning within their own domains. On this evidence, teachers' incorporation of technology into their practice involved 'a measured development in their thinking about instruction, their role as teachers, and… the look and feel of classrooms as the arenas where education takes place' (Kerr, 1991; p. 132).

8. Concluding comments

For the teacher-researchers, involvement in this research afforded impetus to articulate and test out some of their conceptions regarding the role of ICT, to instigate and trial fresh ways of working, and to review emerging issues associated with integrating technology within their practice. For the university research team, the study provided a window onto the development of practitioner thinking about incorporating computer-based tools and resources, during a period of increased policy focus on the provision and use of ICT in schools (DfES, 2003). Notwithstanding the types of curricular and institutional constraints described by Cuban et al. (2001) as inhibiting pedagogical change, there were signs that teachers were thoughtfully and responsively modifying and extending their established repertoires of practice through incorporation of technology, and that patterns of classroom interaction were shifting towards more collaborative ways of working. Moreover, these adaptations, though gradual, appear to be robust. Our recent follow-up study of the participating teachers indicates that they have not only sustained the technology-supported practices reported here and further developed them over time, but that they have also introduced these approaches to their (departmental) colleagues (Hennessy and Deaney, 2004).

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