J. Curriculum Studies, in press

Teacher perspectives on integrating ICT into subject teaching: Commitment, constraints, caution and change

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Abstract

This paper examines how secondary teachers of the core subjects of English, Mathematics and Science have begun to integrate information and communication technology (ICT) into mainstream classroom practice in English schools. It draws on an analysis of 18 focus group interviews with core subject departments. The analysis culminated in a thematic model of professional thinking about how the integrated use of ICT can support subject teaching and learning. Evident commitment to incorporating ICT was tempered by a cautious, critical approach and the influence of external constraints operating. Teacher accounts emphasised both the use of ICT to enhance and extend existing classroom practice, and change in terms of emerging forms of activity which complemented or modified practice. A gradual process of pedagogical evolution was apparent; teachers were developing and trialling new strategies specifically for mediating ICT-supported learning. In particular, these overcame the potentially obstructive role of some forms of ICT by focusing pupils' attention onto underlying learning objectives.

Introduction

The relatively recent introduction of new technology into mainstream schooling was widely expected to penetrate and transform teaching and learning across the curriculum. This paper examines how secondary teachers of the core subjects[i] of English, Mathematics and Science have begun to integrate information and communication technology (ICT)[ii] into everyday classroom practice in English schools. The term ICT encompasses the range of hardware (desktop and portable computers, projection technology, calculators, data logging and digital recording equipment), software applications (generic software, multimedia resources) and information systems (Intranet, Internet) available in schools at the time of the research. Specifically, we investigate how these forms of digital technology are being used to carry out already familiar activities more quickly, reliably, broadly, productively, interactively, and how such use may be re-shaping these activities. In so doing we analyse teachers' conceptions of the motivating and constraining influences upon their use of ICT. This analysis culminates in a grounded model of how technology use might be successfully exploited and integrated into existing classroom practice, and how that practice is beginning to evolve. The implications for the traditional academic curriculum of introducing a powerful set of cross-curricular tools and resources are considered, along with the influences of established curriculum practice and policy upon teachers' willingness to develop new forms of activity and pedagogy.

The paper begins by describing the educational context of the study and elaborating the relation of the research to previous work. This discussion centres on the main factors influencing integration of ICT. The focus group methodology employed in the study is outlined and background information about the six participating schools is presented. The main body of the paper is concerned with the results of the thematic analysis carried out on the interview transcripts. The model being developed characterises the external and internal influences upon integrated use of technology, first in terms of teachers' commitment to integrating use of ICT and the perceived constraints operating in the working context. Within this context we examine pedagogic beliefs in the potential of technology for transforming subject teaching and learning. This involves identifying the key 'affordances' (or perceived beneficial attributes) of using technology in the classroom, and describing teachers' caution and concerns about what accommodating its use may displace or threaten. The final strand of the model concerns change in pedagogy and practice, namely the perceived enhancement of subject learning and the qualitatively different experiences beginning to emerge. This includes a set of strategies for mediating pupils' interactions with ICT which teachers employ in order to overcome some of the obstructive features of certain forms of use.

Research into pedagogic change associated with technology use

The research literature offers little support for the popular (though perhaps unrealistic) rhetoric about technology revolutionising teaching and learning or teachers fundamentally re-working their lesson plans and pedagogy. Goodson and Mangan (1995) found 'evidence of reshuffling the pack of cards, but little evidence of anybody trying a new game' (p.119). (Tearle in press: 11) detected 'few signs of radical alteration to existing structures and working practices, or even evidence of particularly innovative application of ICT'. Similarly, the interim report of a major English evaluation[iii] indicates that 'relatively few teachers are integrating ICT into subject teaching in a way that motivates pupils and enriches learning or stimulates higher-level thinking and reasoning' (p.14). As other studies have found, these few tend to be teachers with an innovative pedagogic outlook already.

Cuban's recent study of Californian pre-schools, high schools and universities with long exposure to ICT confirms that (even in Silicon Valley) use is not widespread or consistent. Classroom teachers are simply using the technology to do what they have always done although in fact they often claim to have changed their practice (Cuban 2001: ch.6). One possible reason is that classroom teachers have historically had little say in designing and implementing development plans for using ICT within their schools, and for defining its role within subject curricula. This is especially true in England and other countries with a centralised curriculum and a corresponding lack of professional autonomy. Imposed policy decisions and mechanical change models often appear unresponsive to teachers' perspectives and their workplace constraints. According to

Olson, they are highly politicised and do not attend to the culture of classroom practice and the pivotal role of the teacher in effecting change. He suggests that integrating new technologies challenges teachers and thus requires innovators to understand and 'engage in conversations with teachers about their work culture, the technologies that sustain it and the implications of new approaches for those technologies' (Olson 2000: 6).

Kerr's (1991) interviews and observations with American teachers who had successfully incorporated technology into their practice indicated that using it allowed 'obvious and dramatic' changes in classroom organisation and management. However technology was not the driving force in teachers' thinking and practice. As well as serving as a 'lever' through which teachers seek to make established practice more effective, technology appears also to act as a 'fulcrum' for some degree of reorientation of practice. Thus, some teachers studied had changed their ideas about their role and authority in the classroom, and others recognised the need for new teaching approaches and skills such as 'information literacy'. However, changes in teachers' pedagogical thinking were slow and measured. Kerr's evolutionary perspective on the processes of (enabling) cultural change throws a damper on the call by some for ICT use to drive radical change. This includes designing new approaches to knowledge acquisition, critical thinking and creative problem solving (Noss and Pachler 1999). The processes involved in creating new perceptions and objectives of teaching and learning deserve closer scrutiny.

Some insight may be derived from theories of mediated action which describe how cultural tools are used to extend learners' cognitive capability; they focus on the constraints and affordances which tools can introduce (Wertsch 1998). Using computer tools helps to decontextualise learning, to make explicit that which is implicit and to accentuate that which is often unnoticed. They uniquely offer new ways to express and make visible key relationships and structures within the subject matter (Noss and Hoyles 1996). The introduction of ICT has the potential to change the system of constraints and affordances which frame activities such as writing, mathematical problem solving and scientific enquiry. The latter are considered to be situated within a social and cultural system, rather than as isolated skills. When learners encounter and accept a rebalancing of the system, this typically results in some modification of their strategies. This study identifies the key constraints and affordances which arise when new technologies are used to support core subject learning. It explores how teachers respond to this shift and characterises their emerging strategies for mediating pupils' learning in this context. Investigating pedagogic change requires an understanding of the key contextual factors in how technology is perceived and used by teachers and these are now outlined.

Motivating and constraining influences upon technology integration

Educational policy and curriculum context

Students' access to technology at school and at home has increased astronomically over the last few years, particularly in the US, Australia, and Great Britain and, to a lesser degree, in other economically-advantaged nations (particularly Finland, New Zealand and Sweden: OECD 2000, ch.4). A host of government initiatives in many countries has helped to dramatically increase the prominence of ICT. Recent examples of ambitious infrastructures created to provide access to on-line learning resources include Sweden's 'Schoolnet', the 'Virtual Agency' in Japan (OECD 2000, ch.9), and the National Grid for Learning scheme in the UK. The latter is one of the numerous ICT initiatives on which the British government has spent 1.8 billion pounds in total since 1997. These initiatives have included extensive training schemes for all new and existing teachers in using ICT in subject teaching and learning.

According to policy makers worldwide, such initiatives should lead to significant technological and pedagogic change within subject teaching. In England at least, however, this rhetoric of 'modernisation' (DfEE 1998) has barely touched curriculum and assessment in core subjects, where a powerful rhetoric of 'raising standards' maintains a view of academic capability as independent of technology use. In this policy context, the National Curriculum (NC) for England and Wales (DfEE 1999) offers only a handful of 'opportunities' for using ICT within the core subjects. These have been described by Leach and Moon (2000, p.390) as at 'best random, at worst banal and inconsequential'. The main reason for this situation is a historical concern with resource issues in schools . Likewise, while some countries such as Denmark, Scotland, Sweden and the Netherlands either require or permit the use of calculator and computing resources in written examinations, regulations governing national assessments constrain the use of ICT in other places (Oldknow 2000). In England, use of ICT is compulsory at secondary level yet statutory tests in core subjects at ages 7, 11, 13 involve no use. A major policy change in 2000 restricted the previously widespread use of graphic calculators in advanced level examinations and coursework. A similar backlash in the US led the State of California to ban calculators from the tested elementary school curriculum (Ralston 1999). In Israel, Hungary, Italy and Poland, graphic calculators are not permitted in final examinations and mathematics educators are campaigning against this (Oldknow 2000).

Not surprisingly, then, appropriate and effective classroom use of ICT is found to be rare (e.g. Ofsted 2001). In practice, established curricula and teaching methods remain in place under a thin coating of technological glitter, and available technology is often underused and poorly integrated into classroom practice. For instance, the recent Third International Mathematics and Science Study [TIMMS] surveys (Martin *et al*. 2000: 239, Mullis *et al*. 2000: 218) found that at least 10 per cent of students reported frequent use of computers in their lessons in both subjects in only two countries – Israel and the US. National teacher surveys paint a similar picture. In the US, combined data from three

surveys showed that only half of the teachers who had access to computers used them in their lessons (Smerdon *et al*. 2000). Likewise, about half of English secondary schools reported 'substantial use' and half reported 'little use' within the three core subjects at the time of our study (DfEE 2000)[iv]. Only two thirds of secondary teachers felt confident to use ICT within the curriculum. Two years later, Ofsted (2002: 15) were still claiming that 'nearly one third of departments have not been affected by the use of ICT' in England. (Note that our concern in this paper is with specialist subject teachers at secondary level. The issues may be slightly different in primary schools, although integrated use of ICT is expected there too.)

In sum, there is a government drive towards provision of opportunities and expertise for using ICT in all schools, yet significant weaknesses are reported in policy and practice. The present subject curricula, assessment frameworks, and policies concerning ICT use seem to simultaneously encourage and constrain teachers in using technology in the classroom.

A further hindrance is that increasing investment in technology infrastructures has not been matched by investment of time and resources to develop new ways of learning and teaching. Despite numerous reported examples of effective use and apparent teacher motivation to develop their pedagogy and practice, clarification of what pupils should learn using ICT – and how teachers could facilitate this – is said to be needed (Ofsted 2001, 2002). Change is likely to be limited without guidance of this kind, and without taking account of teachers' own theories about teaching and learning which are central to integration (Mumtaz 2000). Rogers (2002) and colleagues observed that teachers' reluctance to abandon their existing pedagogy was more of an obstacle to teacher development in classroom use of ICT than limited resources (known to be a major impediment). A Dutch study confirms that professional beliefs about curriculum content, subject pedagogy and managing classroom activities outweighed school factors in explaining change (Veen 1993). The research additionally highlights the importance of personal factors associated with higher levels of computer use by teachers (Becker 2000). These include teachers' openness to change and recognition of the transformative potential of using technology. The converse is that practitioners' concerns about disruption to established pedagogic approaches may lead to caution and additional limits on change.

Policy approaches which ignore personal and professional beliefs tend to construe educational technology as an innovation to be administered and then adopted by teachers. They assume that ICTs are 'merely new educational tools waiting to be picked up and used' (Kerr 1991: 121). Yet classroom change will not arise through simply providing more machines, software and functionality, and demonstrating that using ICT is effective. Selwyn (1999b) argues that the dominant construction of educational computing is indeed technocentric and coercive, limiting integration and educational effectiveness. It underestimates the degree of change required in teachers' understanding and beliefs

(McCormick & Scrimshaw, 2001). However, if ICT is viewed instead as a cultural artefact, as it is here, gradual influences of its use upon pedagogy mean that teachers' practice, thinking, attitudes, roles and approaches to using new technologies evolve over time. These influences are more complicated and significant than the degree of 'take-up' in schools, with which many statistical studies are concerned (Kerr 1991). Indeed the introduction of diverse forms of sophisticated technology adds even more complexity to already intricate teaching and learning processes. A meta-analysis of over 600 studies on ICT in education concluded that 'research struggles to tackle the complexity of the integration of the evolving technologies' (Lagrange *et al*. 2001: 122).

The existing literature has some further gaps which our study attempts to address. Much of this literature is based on large-scale surveys; these tell us something about the scale of computer use and the kinds of applications used but not about the nature and appropriateness of use. There are also in-depth examples of innovatory use in technology-rich environments but little research concerning integration with established practice in mainstream schools (see the extensive review by Mumtaz 2000). Moreover the research in this field comes mainly from the USA, and reflects its distinctive educational culture. Finally the predominant focus of previous research has been on students' difficulties and learning with ICT, so that references to the 'teacher dimension' are sparse (Lagrange *et al*. 2001). In this study, then, we strove to elicit teachers' own perspectives on the internal and external motivating and constraining influences upon technology integration in trying to make sense of whether and how classroom practice is beginning to change.

Impact of subject cultures on using technology

One potentially important contextual factor which shapes how technology is perceived and used by teachers is the 'community of practice' (Lave and Wenger 1991) associated with their subject. This is a social framework within which the planning, support and evaluation of student learning takes place. Each subject community could be said to share a set of tools and resources; approaches to teaching and learning; curriculum practices; cultural values, expectations and aims. In England, as in the USA, the subject department acts as a basic social unit within secondary schools. Departments develop their own perspectives on objectives both internal and external to the school and they shape their actions accordingly (Louis and Firestone 1997). In England, recent educational reforms have led to departments playing a more active part in mediating between government policy and classroom practice. This takes place through the development of departmental teaching policies and schemes of work, namely detailed plans for delivering the NC. The indirect effect of the reforms has thereby been to increase collegiality within subject departments (Cooper and McIntyre 1996, Donnelly 2000). Their sharing of practice and experience will encompass the introduction and integration of ICT into subject teaching (Williams *et al*. 2000, Rogers 2002). Subject departments which work effectively

together as teams may constitute more robust communities of practice than their wider subject cultures.

Subject communities at either level are inevitably subject to ongoing redefinition and adaptation, however. They are responsive to conflict, challenges and dilemmas encountered . The subject practice – here, teachers' knowledge, understanding, skills, attitudes, goals, beliefs and pedagogy – thereby develops over time (Loveless *et al*. 2001). This complex process is not automatically triggered by using ICT or sharing information with colleagues. It entails developing ideas and trying them out, considering the principles and purposes that underpin activities in particular contexts, and critical reflection.

Little research has analysed how (and why) subject cultures differentially affect teachers' use of ICT. A Canadian investigation by Goodson and Mangan (1995) and a British study by Selwyn (1999a) offer notable exceptions. The study by Goodson and Mangan excluded the core subjects and focused on teaching styles and classroom organisation. The main issue the authors identified in introducing classroom computers was that of 'congruence', i.e. how closely the changes fit in with existing subject practices, content and pedagogical paradigms. Teachers are considered to be reluctant to adopt a technology which seems incompatible with the norms of an antecedent subculture. (Goodson and Mangan 1995) concluded that the culture of computing can completely colonise some curriculum areas, in terms of replacing subject learning with technical learning, whilst most commonly, the subject subculture co-opts and colonises the computer, which becomes 'just another tool'. In subjects like English, there may be little congruence or colonisation of either kind. Andrews (2000) claims that 'the subversive, humanities-based, liberal and book-dominated culture of English... is undoubtedly a factor in the resistance of English teachers to new technologies' (p.23).

Selwyn's (1999a) study was heavily based on focus group interviews with students in the 16-19 sector, although 20 teachers were also interviewed individually. Selwyn argues that traditionally, computers were the domain of Mathematics, Science and Technology departments (Culley 1988) and this legacy may still be apparent in the ways in which different subject areas employ computers. While technology is intricately connected with the history of a cultural practice – its development and its role as a learning tool (Lave and Wenger 1991), the computer is described by Selwyn as more congruent with some subjects' histories and more integrated into their practice than others. It thus creates a sense of ownership for some subjects and an unfamiliarity and suspicion for others. Wenger's concept of <u>cultural transparency</u> of the artefacts engaged in everyday practice is relevant here. The cultural significance of technology as an effective learning tool must be highly <u>visible</u>, while – at the same time – its role as a mediating technology supporting focus on the subject matter must be highly <u>invisible</u>, in the form of unproblematic interpretation and integration into activity (Lave and Wenger 1991). Where subject communities resist the integration of ICT, the role of transparency is reversed. Computers

are then highly visible as mediating technologies, obstructing the process of learning, and highly invisible in terms of their cultural significance as learning tools within subject-specific or departmental pedagogy (Selwyn 1999a).

In sum, these two studies corroborate the notion that subject cultures are an important influence in determining teachers' and students' use of ICT. No within-subject variation is described although the strong likelihood of segmental differences within disciplines is acknowledged. There is also evidence that teachers choose ICT applications, activities and approaches to fit their own perspectives on teaching and learning (Niederhauser and Stoddart 2001). Thus pedagogic perspectives vary both within and between subject disciplines, and will influence the evolution of subject practice.

It is also notable that individuals' attitudes, confidence levels, cognitive and emotional styles, and social identities can influence their voluntary participation in the use of ICT ('psychological access': Wood in preparation) and this may apply to teachers as well as students. An increasing body of research indicates that gender and racial stereotyping, in particular, may not only result in inequities concerning differential access, level and nature of use, and perceived competence. These dynamics may also impact on the formation of subject cultures and their tendency to colonise technology, and hence could affect teachers' perceptions of agency and authority in working with colleagues to bring about change (e.g. Turkle 1995). It was beyond the scope of our analysis to investigate these issues but they are flagged up as being of potential interest to subsequent researchers.

Further contextual influences on technology integration

One means of shedding some light on the complexities arising above is to recognise that teachers' involvement with ICT is undoubtedly influenced by the working contexts in which teachers find themselves. Innovation and adaptation are costly in terms of the time needed to develop and establish new practices. In addition to the new interpersonal and pedagogic skills which teachers require to use ICT in their classrooms, other contextual factors which can act as barriers to using ICT include: lack of confidence, experience, motivation, and training; access to resources and timetabled use of dedicated ICT suites; unreliability of equipment; classroom practices which clash with the culture of student exploration, collaboration, debate and interactivity within which much technology-based activity is said to be situated (Hadley and Sheingold 1993, Schofield 1995, Becker 2000, Dawes 2001). These contingencies may cut across subject boundaries and explain some variation within subject communities, whilst leading us to expect greater coherence within school subject departments (local conditions are more uniform although individual perspectives are obviously likely).

Considering teachers as members of the wider community of educational technology users means, according to Dawes, that change occurs in individuals and groups of

colleagues as they develop professional expertise and the motivation to evolve from being 'potential users' (through the stages of 'participant', 'involved' and 'adept') to 'integral users' ultimately.[v] The cultural norms and practices which operate within this wider community are shaped by competing forces, including: senior management and their creation of a supportive organisational culture within the school (Williams *et al*. 2000); the external subject community; education officials, policy makers and inspectors (at local and national levels); in England, pressure from the national assessment regimes and the related emphasis on 'delivery' of a content-led statutory curriculum. Teachers cannot develop their pedagogy without heed to these powerful forces and educators wishing to support integration of ICT into subject teaching need to overcome the organisational and political obstacles arising (Loveless *et al*. 2001), as well as teachers' personal and professional perspectives.

Research aims

In acknowledging the plethora of potential barriers and incentives for using ICT, our characterisation moves towards analysis of the actual – and shifting – context of everyday practice, according to the 'naturalistic' tradition (Cooper and McIntyre 1996) which shaped our research design. This paper investigates the willingness of teachers to embrace new approaches to subject teaching and learning, the perceived constraints upon the process of integrating ICT, and their own reservations about this. Teacher representations of appropriate and effective pedagogy for using ICT to support subject teaching are subsequently characterised. That data is drawn upon in considering the degree of and ways in which integrated use of ICT can transform classroom practice and learning aims.

Design and context of the study

The investigation was situated within an established research partnership between the University of Cambridge and a number of local secondary schools. Developing the use of ICT to support subject teaching and learning had been identified as a priority across the participating schools. The school cultures were thus potentially more supportive than average and the teacher participants were possibly more enthusiastic users of ICT in the classroom. The aim of the formative phase of the resulting project (conducted over the first half of 2000) was to identify and analyse how teachers and pupils perceived ICT use to contribute to successful practice. This anticipated a second, developmental phase in which promising approaches would be investigated in greater depth. Because the wider project had a practical goal of stimulating practitioner reflection on the use of technology as part of a programme of educational improvement, it was important to employ research approaches conducive to this ultimate goal. Consequently, the first phase of the research employed group interviews involving students in three different age groups and teachers in different subject departments. (The pupil data have been analysed and described

separately by Deaney *et al*. 2003). The 'focus group' method has become increasingly evident in social science and educational research (Barbour and Kitzinger 1999). It offers a cost-effective interview technique, and most importantly, a powerful means of provoking informative interaction between participants. Focus groups allow the researcher to explore different perspectives within a social network and how these are articulated, challenged and developed through interaction and in relation to group norms.

An important consideration was group composition. The unit of observation for the study is the school department concerned with each of the core subjects, i.e. the 'naturally-occurring' decision-making group (Kitzinger and Barbour 1999). The focus was nevertheless with comparing ideas across, as well as within, departments.

General characteristics of participating schools

The working context of the research partnership dictated an opportunity sample of six state secondary schools, all located within 50 miles of Cambridge. Basic information about each is given in Table 1. Pseudonyms have been adapted from official designations, and the corresponding abbreviated codes will be used henceforth to indicate sources for quoted material. Although some of the schools had – or aspired to have – specialist status as indicated in their pseudonyms, none operated a selective admissions policy.

Insert table 1 here

Further relevant data were extracted from official performance tables (dated 2000) and inspection reports on individual schools (dated between 1996-99). The proportion of students entitled to free school meals is a standard indicator of social disadvantage: two schools – Community College and Girls School – lay close to the national median for schools (14%) on this index; and the remainder showed markedly lower levels of disadvantage. The proportion of students gaining the benchmark of 5 or more higher-level (A-C) GCSE examination passes at age 16 is a standard indicator of academic success: two schools – Community College and Village College – stood a little above the national median for schools (45%) on this index; and the other five showed markedly higher levels of academic success. Against national norms, then, the schools in this opportunity sample were relatively socially advantaged and academically successful.

Use of ICT within participating schools

All of the schools had been inspected within the four years preceding the study. While caution has to be exercised in interpreting inspection reports produced by different teams at different times, these do provide a form of independent judgement on previous histories of ICT use in the schools. Broadly, the comments about use of ICT were generally more favourable regarding Mathematics[vi], quite varied regarding English, and less favourable regarding Science. In Village College and Sports College, poor access to ICT facilities was a major constraint in all subjects. Use was generally under-developed –

except in mathematics – at Community College, and at Girls School where limited access restricted opportunities. At Media College and Technology College, the two most highly resourced schools with specialist status, use was relatively developed but markedly inconsistent.

Poor access to ICT facilities seems to have been an important factor behind many of the critical judgements. In all of the schools, making use of computers to support teaching and learning depended primarily on gaining access to specially equipped ICT rooms. These were greatly in demand and often timetabled for other uses. In sum, access to facilities was opportunistic and problematic in most schools and the percentage of curriculum time using ICT was small in all subjects, although there were some differences in access between disciplines. Within Mathematics, two schools (MC and TC) enjoyed departmental ICT rooms and four departments had their own set of graphic calculators. Science departments had the best level of provision. Only TC had a dedicated departmental ICT room but all of the other schools had some computers plus data-logging facilities within laboratories. English departments appeared to be the least well resourced since none had their own facilities at the time.

In each subject, similar ICT tools and resources were in use across the six schools. The emphasis in English was on word processing, desktop publishing, multimedia resources and the Internet. In Mathematics, all schools used spreadsheets, and most also used Logo, graphing tools, and courseware or Internet revision sites. In Science all schools used data-logging facilities, multimedia resources and the Internet; and most also reported using spreadsheets, and courseware or Internet revision sites.

Despite their somewhat atypical profiles in terms of social advantage and academic achievement, schools and departments were not selected as – nor found to be – particularly innovative or even well-established in their use of ICT.

Investigative strategy

This study was based on a series of focus group interviews held with the Mathematics, Science and English departments in each of the six participating schools. Given the heavy demands on teachers' time, not every member of the department in some schools was able to participate. Lasting 45-70 minutes, the sessions were facilitated by members of the project team – either from the university (mostly) or another participating school – who were not themselves teachers of the same subject. This 'outsider' audience was intended to encourage department members to articulate ideas which might otherwise have been taken for granted.

The interviewer adopted a positive stance, with the main prompt requesting examples of ICT use which participants felt had been successful in supporting teaching and learning.

Typically, this elicited accounts of several examples, often guided by attention to the content of the departmental schemes of work for each year group. When examples started to flag, a secondary prompt asked participants what impact they thought ICT was having on teaching and learning in the subject in question, with follow-up probing for detail. Time permitting, further prompts asked participants about the impact of government initiatives on their use of ICT, and their ideas about future developments in this area.

The audio-taped sessions were transcribed and segmented according to shifts or breaks in the focus of attention. The transcripts were edited into relatively short units of talk nested within more sustained episodes. The resulting transcripts were imported into a computer database (using QSR NUD*IST) to facilitate a recursive process of thematic organisation through constant comparison (Glaser and Strauss 1967). This led to the construction of prototypical categories, grouping together related material. The goal was to identify well-developed themes running across transcripts from each subject discipline, and to examine relationships between these themes. This led to the omission from the final category system of some marginal ideas which did not meet these conditions. However, some themes encompassed contrasting opinions or descriptions concerning the impact of using ICT and these are described, where significant. The analysis process involved developing a provisional coding framework via close scrutiny of the data, using the participants' own language where possible (in vivo codes: Strauss 1987). Further reflection and discussion amongst the research team – in conjunction with consultation of related research literature – subsequently yielded a revised organisation of the categories into wider (analytic) themes. This was then employed for final coding of all of the transcripts. In sum, the data were treated as a field of inferences in which patterns (e.g. across subject departments) were identified, their validity was tested, and alternative interpretations were explicitly evaluated (Hammersley and Atkinson 1983, ch.1). Our approach therefore drew additionally on the 'grounded theorising' model of research (Glaser and Strauss 1967).

Scope of the analysis

The analysis investigated teachers' perceptions of the contribution made by using ICT, its impact upon subject pedagogies, and the extent to which ICT is integrated into classroom practice in these areas. Thus, it was important to understand when – and why – activities did not benefit from the introduction of ICT, so qualified reports of success and negative views were included. It was considered important too that any conclusions should be grounded in actual experience, thus speculative claims were omitted from the analysis.

Factors concerning the physical, socio-political and educational contexts of ICT use undoubtedly affect teacher motivation to use ICT. Those arising in our interview data mainly concerned obstacles to wider and integrated use (particularly access, timetabling and reliability of resources; time available; impact of government initiatives, including policy, curriculum, standardised assessment and inspection). These contingencies – and

also levels of teachers' technological capability, experience and confidence – are fairly well documented elsewhere. Therefore, some of these issues were not explored in detail. Exceptions include the most critical factors of departmental access to ICT facilities (introduced above), external curriculum and assessment requirements, and teacher expertise and confidence with technology.

Evidence of collegiality within interviews

There were some striking between-subject differences in evidence of collegial thinking regarding ICT use. In Mathematics and Science, interview talk often involved reference to shared ideas and common experiences. Individual opinions were of course expressed but these were rarely conflicting and much of the talk centred around collective policy making and collaborative planning concerning ICT use. In Mathematics there were 19 explicit references to departmental 'schemes of work' in the context of ICT use (distributed across all 6 of the departments). In Science, there were 15 such references (spread over 4 departments). Collegiality was signalled by the notable way in which colleagues would reinforce, continue and extend each others' comments (as will be seen in forthcoming quotations where / indicates a switch of speaker). When potential breakdowns in public consensus did occasionally emerge, they tended to be repaired by finding common ground, or simply passed over. Finally, the high level of use within interview talk of the collective first person pronoun 'we' was striking, occurring almost as frequently as 'I' in these interviews, compared to just over half as frequently in the British National Corpus of talk in similar circumstances.

Explicit disagreement was likewise rare in English departments, but the flow of interview talk often came over more as a series of individual contributions. Comments sometimes followed up a topic but they rarely affirmed or explicitly built upon what had been said. Corroboration for such impressions comes from a 'we' to 'I' ratio similar to the British National Corpus, and considerably lower than in other subjects. Equally, there were only 3 references to departmental 'schemes of work' and these highlighted a lack of incorporated ICT use (occurring over only 2 departments). The greater disparity in views within the English departments did not prevent a number of strong subject-specific themes emerging both within and across departments – in Mathematics and Science too – which built up a coherent picture of the ways in which teachers and pupils use ICT.

We now describe the thematic framework resulting from the analysis of teacher views concerning the use of ICT in teaching their respective subjects. In the first two sections we set the scene by considering whether and how core subject teachers have begun to integrate the use of ICT into their classroom practice, and the complex internal and external influences upon doing so. This provides a frame for examining teachers' pedagogic beliefs and reservations in the third section. These include the affordances of the technology and the conditions under which they are willing to use it, particularly in comparison with other approaches. Emerging strategies for mediating pupils' learning

with technology are outlined in the fourth section, followed by a discussion of further ways in which subject practice is changing.

Commitment to integrating use of ICT in subject teaching

Degree of reported integration of ICT into schemes of work

Interview comments about already achieved or intended 'integration' into schemes of work (emerging in all departments except two English ones) were mainly favourable but they portrayed very mixed levels – and uneven rates – of integration. Differences were evident, not so much between subjects, but between schools with very different levels of ICT provision and departmental access. (Consequently, while our analysis does not on the whole focus on contextual differences between schools, an important exception is made here.) In Technology College, use of ICT was most intensive and had unequivocably been incorporated into schemes of work in Mathematics and Science. Teachers attributed this partly to the specialist status of the college and the resulting improved access to equipment. In science, integration was regarded as important in ironing out inequities between pupils across the 'digital divide': 'By putting it in a scheme of work you then mean that people who don't have machines at home are at least getting their access to ICT...' [TC/Sc]. In contrast with their Mathematics and Science colleagues, English teachers at TC did not enjoy the luxury of a dedicated IT room; having to rely on opportunist access to less advanced equipment resulted in extreme frustration at not being able to implement their ideas and plans for exploiting the potential of ICT. Thus lack of use was attributed to factors beyond their control rather than resistance:

> I can't stress how bad we feel sometimes about the frustration, simply the lack of equipment, the lack of maintenance and so on. It is a massive issue... The criticism is not as a result of Luddism… but it's a double-edged sword... the fact that the machines do not deliver what they promise… but… we want to use this stuff. [TC/En]

In Media College, use of ICT had similarly been written into schemes of work in Mathematics and Science, and this was formally monitored. Lack of reliable resources was regarded as a potential barrier to the full integration of ICT into subject teaching here (and at other schools). Variation present in teaching approaches within the mathematics department was anticipated to reduce as a result of getting their own suite of computers. The department was described as 'under transition' and the integration of ICT in progress was regarded as a positive step towards making more effective use of it rather than 'go and use it because it's your turn on the timetable'.

Again, the English department at MC possessed fewer ICT facilities and had not achieved the same degree of integration, although they were in the process of rewriting schemes of work to incorporate planned opportunities for using ICT – albeit with some concern about appropriate use:

> It has to be something… that just becomes a part of what you do, not 'Oh today we are going to use the computers' which is a problem for us at the moment, as a department, that it's seen as something different and therefore it can be used and abused. [MC/En]

The only other department where use of ICT had reportedly been integrated already into schemes of work was the Mathematics department at Sports College. Here, difficulties in managing the range of pupil expertise with spreadsheets had prompted production of a particularly detailed and structured scheme:

> One of the big difficulties that we used to have… was that we had a blank spreadsheet and an investigation to complete. But people would start it at different points… so I think I taught some horrendous lessons on it… the wide level of differentiation required within a classroom, and because of the lack of anything on there to help, made it almost impossible to teach that. [SC/Ma]

At Community College, departments had either not written use of ICT into their schemes of work (English) or were in the process of rewriting them or were planning to do so (Maths, Science). These findings are consistent with the fact that CC was one of the two less socially advantaged schools, and in the early stages of ICT use. Girls School was in a similar position and teachers there had not yet started rewriting schemes of work to incorporate ICT. They too talked about the need (and perhaps pressure) to do so, and about making more planned use of ICT in the future, avoiding the 'what shall I do today sort of thing' [GS/Ma].

At Village College, the English department made no mention of a departmental scheme of work although teachers enthusiastically described many examples of using ICT. They reported that 'it doesn't have the major impact we'd like to see' owing to constraints of time and access to facilities. The Mathematics department had reached an impasse for exactly the same reasons: 'It's not worth doing it at the moment because you're not able to take your class in there' [VC/Ma]. Their Science colleagues reported that integrating ICT into their scheme of work had not yet been a priority, although they planned to write data logging in and to ensure that it was done consistently and assessed.

Teacher expertise and confidence in using ICT

Reluctance to use ICT was more evident in English and Science, perhaps because teachers in these subjects lacked the support and the collective experience which the fuller integration of ICT use into schemes of work provided for many of their Mathematics colleagues. Experienced teachers who are used to other approaches and tools can feel uneasy about using ICT in the classroom, even though many possess technical skills: 'Two colleagues… let's just say women of my age… are a bit more resistant still… They're both very confident users of IT and both use it themselves a lot, but not so confident with using it with pupils' [CC/En]. Others were anxious about lack of expertise, describing 'a steep learning curve' and feeling 'quite frightened of getting it wrong' [GS/En] or 'stupid asking somebody' [VC/Sc]. This again results in a lack of confidence to use ICT in lessons:

> I mean I can't write brilliant poetry, but I can teach them how to write poetry and they write better poems than I do. So ICT must be the same in a way, but it doesn't feel like that. It makes me feel scared. [GS/En]

Teachers felt that the real benefits of ICT will only be felt when confidence is increased: 'I think it has the potential to [change the way Maths is taught], but only when everybody in the department feels confident enough to be at a level where they can confidently teach students how to use IT' [MC/Ma].

Another implicit impediment to the use of ICT was the perceived lack of control over learning processes, stemming from lack of expertise or of adequate equipment:

> …at the moment it causes one hell of a lot of frustration and irritation and demoralisation as a result of… a break in something we're used to, which is having control over the direction and the content and the substance of a lesson. For most people that control is lost in a computer room. [TC/En]

External influences related to curriculum, policy and assessment

Tension between subject and ICT skills

Despite the widespread commitment to integrating ICT, it was clearly accompanied by a feeling of externally imposed pressure. This relates to the statutory requirement within the English National Curriculum to use ICT within subject teaching, and the imposition of a series of ICT initiatives, as discussed above. The effect of these top-down policies has been a perception of eroded autonomy and a feeling of disempowerment in teachers. One notable factor affecting integration was the perceived conflict concerning whether to use ICT in order to facilitate subject learning, or whether the emphasis should be on demonstrating ways in which ICT can be used and teaching technical skills. Teachers in all subjects were concerned with: '…trying to get the balance right between ok, here's a Maths problem, use what you know to solve it, or here's how you use IT to do something' [MC/Ma]. However, teachers in half of the departments interviewed felt that they had to include ICT in schemes of work regardless of whether it is particularly useful for that aspect of the curriculum or its use is contrived. One teacher described a weak Science activity which was used to teach IT skills [VC/Sc], and another mathematics teacher wanted 'more in terms of ICT as the servant of the curriculum rather than the other way round', the irony being that 'the calculators have got in the way of the learning point' [SC/Ma].

Some teachers were concerned that they need to spend time with pupils helping them with ICT skills, thus decreasing the amount of time they can spend explaining subject-specific concepts: 'It tends to be the children who are least able and need most help… you can spend your whole lesson teaching them how to do something with the computer and they wouldn't have learnt any Science at all...' [CC/Sc]. The issue of achieving a satisfactory balance between the objectives of subject learning and ICT training was also salient for the Science teachers studied by Finlayson and Rogers (2003). In our study, the tension between the recognised pressures of an overloaded curriculum in Science and the

pressure to incorporate use of ICT was felt particularly keenly in one department where concern was expressed that increasing use meant throwing out other parts of the curriculum in order to 'fit in' ICT. This was related to the notion of 'colonisation' described by Goodson and Mangan (1995) and seemed to assume that ICT would be added on in a time-consuming fashion which would displace other components:

> We haven't been able to see, within our schemes of work for instance, how we can provide time… we've had to work backwards to try and work out what we can afford to chuck out! ...So perhaps it hasn't been a high enough priority, I don't know. [VC/Sc]

There was some confusion and anxiety about what should be taught within core subjects and which skills should have already been gained in ICT lessons. Consequent uncertainty about pupils' competence levels resulted in difficulties in planning activities: 'I wasn't actually aware of where they were in their IT lessons, so I wasn't quite sure what they were capable of…' [SC/En]. These findings have important implications for school policy; subject departments tend to operate independently in many cases and opportunities for sharing knowledge about what pupils are doing in different subjects can be limited. A conscious effort is needed to create those opportunities, particularly with a cross-curricular subject like ICT, and to clarify departmental responsibilities.

Conformity to external regulations

The interview comments indicated that teachers experienced both a pressure to use ICT and a desire to exploit technology and change pedagogy accordingly, but at the same time, a set of constraints on that use. Apart from those limiting factors internal to the school and the individual, already discussed, there was a perceived tension between using ICT and needing to conform to external requirements of traditional examinations. Requirements to use technology to enhance learning without recognition through assessment was deemed problematic. In three mathematics departments [GS; MC; VC], the folly of the exam requirements taking practice backwards in time was emphasised. There was concern about using ICT, particularly graphic calculators, being disadvantageous for students' performance. For example:

> ...now what do the exam boards and Government say, well because these calculators have got so powerful we're going to stop you using them… When you do your driving test they don't test you in your horse and cart, it's what you can make of this modern machine… that's something that worries me about us pushing to be using computers in the classroom, graphical calculators... the sorts of things it's good at learning, they can't be tested on in a written examination. [VC/Ma]

At MC, the concerns expressed led to teachers actually dampening the enthusiasm for using ICT:
'I think it's our job as teachers to be quite conservative in just how much we educate them in what a computer perhaps can do' [MC/Ma]. The impression here is of conformity to external regulations severely undermining the use of ICT. Most of the views expressed were ones of dismay and resistance to the notion of discarding use of ICT in response, though teachers were fighting a losing battle here and ultimately did succumb to the

pressures imposed. Teachers at VC described 'being beaten by sticks': 'So however important it personally may be to educate a child to use this wonderful piece of machinery… I must concentrate… on getting them that qualification' [VC/Ma].

These findings relate to those of Selwyn (1999a), who asserted that for many teachers (especially at post-16 level), subject pedagogy is dictated by the nature of the qualifications being taught and the final examinations. ICT must take second place next to guiding students through passing exams. A recent Greek study confirms that teachers cautiously adapt the use of ICT to the traditional teacher-centred mode of teaching, which is strongly connected to the established examination system (Demetriadis et al., 2003). The OECD report (2001) argues that existing inflexible patterns and means of assessment (written tests of knowledge) place a stranglehold on the curriculum and act as a brake on imaginative uses of ICT. Papert (2001) too asserts that the recent frenzy of testing and curriculum standardisation is preventing the biggest potential change in the means and goals of learning, and that schools are being left behind by a rapidly changing society. The teachers interviewed likewise perceived the consequences as regressive. In our study, interestingly, this issue was highlighted in mathematics, where the explicit bans on calculators seem to have brought this issue to the fore (Jarvis and Woodrow 2001). To conclude, new assessment systems are needed to address the new kinds of skills and knowledge which using ICT can help to develop. Nevertheless, in Science too, the emphasis of official assessment on manual laboratory skills mirrored an important concern of teachers, who also portrayed a traditional work ethic valuing the 'effort' displayed by pupils:

> We're assessing their skills of being able to use equipment skilfully and accurately, like thermometers, and… you've got some pupils who come back with graphs produced on their computers and have they put in as much effort as the kid who's hand drawn the graph? [VC/Sc]

Emerging pedagogic beliefs concerning integration of ICT

Having identified the key external forces operating in the working context of secondary subject teachers, we turn now to their professional beliefs and concern about the benefits of using technology in the classroom.

Perceived affordances of technology use

Our characterisation of effective pedagogy for using ICT to support subject teaching yielded a set of themes describing the affordances which teachers perceive as related to effective use. These pedagogical themes are outlined below and further illustrated through teacher quotes in subsequent sections (Ruthven *et al*. submitted-a, provide more details for interested readers). The themes were largely concerned with ICT being used to support, enhance and extend existing forms of subject teaching and learning. The degree of congruence with established methods and goals which they portray is consistent with

the 'incrementalist' view (Schofield 1995), whereby use of ICT is assimilated to ongoing subject practices and the established curriculum. (The themes shared some commonality across subjects, but also reflected particular emphases and concerns of teachers in each subject.) The contribution of technology use was conceptualised in terms of:

Effecting working processes and improving production – increasing productivity related to speed and efficiency of routine processes (e.g. using ICT tools for data handling and graphing); increasing lesson pace; offering more 'precise', 'reliable' and 'accurate' procedures; promoting more professional presentation and adding to the 'quality and pride' of pupils' work (particularly using word processing and desktop publishing tools);

Supporting processes of checking, trialling and refinement – providing 'immediate feedback' and encouraging 'self-correction' (e.g. spell checking or using calculators and spreadsheets to check the results of manual calculation and graphing); supporting problem-solving strategies through repeated 'trial and improvement' of conjectured solutions; promoting 'experimentation' and 'playing around' with texts; facilitating editing and continuous redrafting; offering opportunities for investigation and exploration when introducing or reinforcing ideas; increasing pupil willingness to 'have a stab at something' and to revise their work or ideas;

Enhancing the variety and appeal of classroom activity – changing the working ambience; reducing the 'laboriousness' and 'tedium' of work; increasing motivation, engagement and hence participation of students in classroom work, through providing 'novelty' and 'variety' and creating 'interest' and 'excitement' and 'adding more fun' using 'a different teaching and learning style';

Fostering pupil independence and peer support – offering pupils more 'responsibility for doing the learning', 'autonomy', 'ownership' and opportunities to share their expertise with peers or provide mutual support, particularly where teacher confidence with ICT was limited and pupils were 'more self-sufficient' ('you're freeing them to do things that really show their potential');

Overcoming pupil difficulties and building assurance – alleviating difficulties encountered in writing, drawing and graphing by hand, so removing the associated disincentives and pupil resistance; increasing motivation and accessibility particularly for less able pupils or those with special needs (e.g. word processing 'gets around' pupils' 'pen to paper motivational problems' and poor spelling and handwriting); increasing pupils' persistence, confidence, satisfaction and sense of pride – through making revision easy, immediate and invisible, reducing perceived criticism, and improving presentation;

Broadening reference and increasing currency of activity – opening up access to 'up to date and broad ranging' and 'more modern, novel' information resources, via Internet use in particular; enhancing the authenticity of tasks (e.g. bringing the 'living world' of Science into the classroom and 'it comes to life'); offering significant contact with wider ideas; providing opportunities for serendipity and enrichment of learning;

Focusing on overarching issues and accentuating important features – in facilitating or automating routine and laborious procedures where pupils 'get bogged down', the use of interactive, experiential and dynamic tools such as simulations, spreadsheets and graphing technologies: allows pupils to 'visualise processes' and relationships, focuses attention on overarching issues, increases salience of underlying concepts and features of situations, helps students to formulate new ideas or 'access a higher learning point'; similarly, pupils' use of computers for writing can 'free up their thinking' or highlight features of texts such as paragraph structure.

The themes identify a range of perceived practical, motivational and educational benefits which underpin teachers' evident enthusiasm for using ICT. However, lest readers interpret this overview of teachers' accounts of successful computer use as overly optimistic or deterministic, it must also be made clear that many of these accounts were also qualified to some degree. These qualifications illustrate teachers' caution with respect to unthinking or counter-productive uses of technology and they are summarised in the following two sections.

Discerning use of ICT and the fit with learning objectives

A widespread concern that use of ICT in subject teaching and learning needs to be 'fitting', i.e. appropriate, discriminating or oriented towards the learning goals of the subject itself, emerged consistently across the data (in all subject departments except one). Teachers proved resistant to the notion of 'bolting on' ICT to the curriculum or using it simply because it is available or its use is encouraged or expected: 'He thought they should use… spreadsheets… but I can't see how you could introduce that into English, unless it was under the most contrived circumstances...' [CC/En]

> I detect a small conflict of interests. I always feel it's my job to co-ordinate the IT, and… to push as much IT into the scheme of work as is possible. But that's always battling against… am I actually achieving anything… or is it really just being there for the sake of being there… almost justifying the existence of having 60 machines in my room. [TC/Ma]

Conversely, comments emphasising the importance of using ICT critically, in terms of 'adding value' (rather than 'bells and whistles') to learning activities, were widely expressed in all subjects: 'What goes on in the class and how you use the computer and when the computer benefits the teacher and the pupil. This has to be something which we evaluate all the time' [GS/En]. 'So the investigations that they're given are ones where it is appropriate for them to do this… tasks where it would be very difficult, or impossible,

without the ICT' [SC/Ma]. 'You always have to think, is there any other way I can get this across? Am I just using it because it is a computer?' [MC/Sc]

Teachers did not automatically assume that because technology is being used, learning is being facilitated:

> We'll have to be very discriminating about the use of those, so that they actually do benefit teaching and learning, and not so it becomes like… come into the Science Museum and you can press all the buttons, but not necessarily come out with any more than a pencil with a dinosaur on it. [TC/Sc]

Their concern led to selective use of ICT and deliberate avoidance of overusing it:

> We are very focussed on learning and how is it helpful to learning; we're not taken in, are we, by ... putting it onto a screen? We are very, very particular about anything that we try to do would be moving learning on. [SC/En]

> ...one of the great dangers is that we do consistently look and say, what is appropriate use of ICT, what is going to benefit the pupils, i.e. what can we do that's better than we could do otherwise? [TC/Sc]

Our interview data clearly show that the teachers recognised that how technology is used, and for what purpose, are critical. They were consciously striving to use ICT where it is appropriate to do so and where it enhances learning – but whether they explicitly monitored or comparatively evaluated the impact on progress is uncertain in the majority of departments.

Comparison and complement with established learning activities

Implicit in the notion of 'adding value' is teachers' concern with using ICT to enhance activity above and beyond what other learning approaches and materials can offer, and this was sometimes made explicit: 'So many Web sites are just downloaded York notes… but you might as well photocopy York notes really' [CC/En]. 'I don't really want it to be an electronic book. It's accessing a different medium but it's not making things any quicker, it's not giving any additional information. We want it to somehow enhance what we do' [CC/Sc]. The contrast or comparison between ICT-supported and other activities is a recurring theme, particularly in English and Science, as many examples discussed earlier portray. Teachers in four English and five Science departments made explicit reference to contexts where the use of ICT was advantageous, and similar numbers referred to contexts where it was not. For instance, books were perceived as having advantages over information obtained from the Internet: school library books contain more suitable information, and the serendipity stemming from browsing the shelves was seen as being eliminated when pupils have direct and immediate access to electronic information sources.

Teachers of all subjects were also concerned that (over-) use of ICT may detract from the teaching and learning of 'basic skills' still required – and assessed – in their subject. In

particular, whilst the use of ICT can save time, effort and increase accuracy in outcomes, the price to pay might be loss of pupils' ability to obtain such results manually. Examples included handwriting skills being eroded [GS/En], basic numeracy skills becoming weak through using calculators [MC/Ma], and the ability to take accurate readings being lost [CC/Sc].

Another theme relates closely to teachers' concern with using ICT only when its value in enhancing teaching and learning activities is clear and their recognition that established activities and skills retain some value in the age of digital technology. This is the notion that using ICT 'complements' other essential activities (in English and Science): 'Just because it's on a computer screen, doesn't make it any better in terms of the impact in terms of your thinking and learning… but the two things have to be complementary' [GS/En]. 'These particular [CD-ROMs] are on 'Elements, Mixtures and Compounds'… and they're just very good at explaining those ideas. They complement, if you like, the wet Science that we do in the lab' [VC/Sc]. The clear implication is that using ICT cannot replace some important aspects of subject practice, particularly hands-on experience. There is a general anxiety among teachers (particularly in English) about losing core features and values of their subject culture, considered to be of paramount importance: 'Discussion is a very, very important part of English and we could never really lose that' [MC/En]. 'I wouldn't want to do away with the pleasure of handling a book and sharing reading in a group' [SC/En]. 'Practical work; there's no substitute, is there, for pupils actually getting hands-on experience and using the equipment themselves' [SC/Sc]. Although many English teachers saw ICT as incongruent in many ways with their subject culture, some mentioned positive affordances at the same time, illustrating the balance in their thinking:

> I mean, this partly pains me because I'm really into the culture of pens and ink and handwriting, but it is good that you can walk round, stand behind people and point to things that they've done and get them to reconsider it, or whatever, in a way that you can't do so easily with writing. [VC/En]

Teachers' concern with preserving their subject culture inevitably led to some pockets of resistance to using or over-using ICT, again in English particularly, where pupil preference for using it was deemed insufficient [TC/En]. Comments included: 'It has no intrinsic value, as far as I'm concerned, at all… in fact, intrinsically there are probably a good number of things that are extremely dark about it' [TC/En]. 'I suppose a concern of ours is that if it goes too far someone somewhere will realise that actually the students do very little other than learning how to operate it successfully…' [MC/Ma]. Nevertheless, a sense of the inevitability of change arising with ICT use emerged:

> I think there is a sense in all of this of Canute holding back the waves… I think the day is fast dawning when the kind of intrinsic value that is placed in things like handwriting,… knowing how to spell, are going to disappear completely. Now, if you rue the day when that happens then you're either someone of great integrity or you're… a bitter, twisted old reactionary. But it's going to happen. [TC/En]

Like their Mathematics colleagues, Science teachers were generally enthusiastic about the use of ICT as long as it is appropriate, although they did express a wariness of being swept away by the rising tide:

> I think there are dangers… I think things are moving at such a pace that we're not… seeing the long-term effects that happen. I'm wary. / No… I don't think that we should curb the use of IT. I think that as time goes on it's going to become more and more part of our lives and… God forbid, but it could almost replace the laboratory. [VC/Sc]

The above findings have implications not just for individual teachers planning classroom activities using ICT but also at the earlier stage of integration into departmental schemes of work. We can conclude that ICT is seductive to teachers but that they feel the temptation for mechanical or inappropriate use must be resisted, and the focus on learning objectives maintained. Teachers' caution in such situations where use of ICT could be unproductive for learning led to the recognition that they needed deliberate strategies to mediate this process. They identified significant ways in which it could become important to actively structure and channel activity; to direct pupils' attention towards issues of substance and away from a superficial concern with presentation (especially in English); to encourage reflection by pupils and engender their appreciation of subsidiary procedures being carried out automatically by the computer; and to develop critical interpretation, analysis and filtering of electronic information (in Science and English). The following excerpts illustrate these considerations, and linkages between them.

Changing pedagogy: strategies of teacher mediation

Some comments identified a need to define, structure and maintain control of learning activities, particularly when starting some new form of ICT work, or working with less academically successful pupils: 'What's important is to have nice clearly defined tasks… [so that] you actually see the fruits of it' [TC/Ma].

> The outcomes have to be clearly defined, particularly with a low-ability group. / …They all hand in, basically, what Encarta churns out… Editing of that requires a great amount of skill on their part, to be able to decipher what's useful for them. So a way round that, for the future, may be some specifically-directed questions so that they can find that information and know exactly what they're looking for. [CC/Sc]

However, a desire to balance such structuring of activity with more exploratory work was also evident: 'I think sometimes you need to channel them and sometimes they need to go off on their own route and explore what they want to explore' [TC/Sc].

> If you… give them like just a basic worksheet with all the things that they can do on LOGO… they come out saying that if you do this repeat pattern you get this… it's more investigative and they find out, it's more of an experimental approach, rather than structuring them. [GS/Ma]

Teachers were concerned to discourage superficial use of software features and overemphasis on presentation/layout which can mask underlying learning goals or disguise deficiencies in work produced:

> I think there was a danger in English that we would go to superficially well-produced, good-looking stuff that, when you actually read it, was very weak. But I think we've moved, certainly with the more able children, through that period very quickly and you get good-looking work that also is of good content. [TC/En].

Again, however, explicit guidance of pupils was seen as important in achieving this: 'We've got to say exactly what it is we're looking for – haven't we. Like, I am looking for the way we are using language in this. I am not looking for something that looks beautiful and it's gibberish' [CC/En].

Such concerns led some teachers to employ strategies in which a degree of working 'by hand' was retained, seen as ensuring 'that the medium doesn't become the message'. There were reports of requiring initial drafts of work to be hand-written, as a way of focusing attention appropriately. Similarly, one account referred to requiring the laying out 'by hand' of computer-prepared text through a 'literal cut and paste' on a sheet of paper: 'When you're doing the writing, you're focusing on the writing – that's so important…the proforma wizards… for things like leaflets, can so easily be foregrounded and the actual use of language gets pushed into the background' [CC/En]. Likewise, while some comments reported that using ICT can facilitate pupils' reflection on their work, others noted how strategies might be needed to help pupils avoid unthinking use of automatic spellchecking and similar facilities:

> They've got a word underlined and actually getting them to maybe not use the dictionary facility, but to say 'Well what do you think might be wrong with it?' – because obviously that can become an issue that they can self-correct without actually thinking through the process of why what they wrote is wrong. [MC/En]

Science and maths teachers similarly asserted that deliberate efforts were required to use time effectively, focusing pupils' attention on underlying concepts, processes and purposes: 'We got an awful lot of pretty graphs which meant absolutely nothing… So we decided we'd concentrate a bit more on the maths the next year' [GS/Ma].

> It's all very well having all these computers and probes and things [but the danger is that pupils do] not realise that really at that particular time you're just using it as a thermometer. You know, if you're weren't careful and sensitive about how you used it, you'd ask them what the experiment was about and they'd probably draw you a computer with all the probes and have no idea what you were trying to achieve. [SC/Sc]

Again, in some departments, retaining some use of manual processes was the preferred strategy for tackling perceived problems in which overly mechanical uses of ICT obstructed the process of learning. Examples included drawing graphs and lines of best fit by hand [GS/Sc] and using an ordinary thermometer: 'Because it's a more manual system they can see more and watch what's actually going on there. Whereas there's a type of 'black box' approach to the measuring with the data-loggers, which I don't think helps understanding' [VC/Sc]. Technology can play an invisible mediating role in learning

through supporting focus on and visibility of the subject matter (Lave and Wenger 1991), as our theme 'Focusing on overarching issues and accentuating important features' describes. It seems that where this fails and the reverse happens (i.e. the mediating role becomes visible and obstructive rather than transparent), teachers need to devise strategies which fulfil that role.

Retaining manual processes was also perceived as important in avoiding the deterioration of 'basic skills' referred to above. This could be overcome by pupils learning to carry out certain processes and activities by hand before incorporating use of technology, according to teachers in five departments. For example, knowing a formula before using it in the computer room [CC/Ma] and developing handwriting skills before word processing, similar to being 'able to tell the time before you should have a digital watch' [TC/En].

Finally, in making use of information gained from electronic sources, especially the Internet, comments from all English and four Science departments (yet none in mathematics) emphasised the importance of 'critical literacy' (e.g. Collins *et al*. 1997). This is linked with the need for interpretation and analysis, including assessment of the originator's agenda and authority, and relevance to the topic under study: 'I'd like to see some thought given to who's presenting this information? …What's its purpose? And to get some really sharp critical skills developed amongst students…' [VC/En]. Attention was drawn to the misleading 'authenticity of print… [which] you trust… because it looks good' and to students' view of the computer as 'as some kind of technological God, that spews out something that's bound to be utterly true' [GS/En], encouraging an unquestioning acceptance of information. Teachers stressed that 'there has to be a reading through and drawing out the salient points and making it your own' [MC/En].

It seems that the required skills are complex for pupils and are only just beginning to be taught and to become evident. This is perhaps because they are only sketchily identified in the NC and not assessed. Some teachers considered that the speed and ease of downloading and printing out chunks of Internet material in fact rendered plagiarism more of an issue than children copying chunks of information from a book or encyclopaedia has been. Educational texts and resources already incorporate the screening and structuring which teachers often found lacking on the Internet; they pointed to how material had already been filtered to be reliable in origin and appropriate for the level of working.

In sum, the need for critical literacy may be enhanced by using ICT, and some teachers recognise that they have a role to play in actively developing this and in focusing research tasks for pupils – as in the suggestion of 'specifically-directed questions' [CC/Sc] elaborated above. English teachers in particular have found ways in which changing elements of the task can help avoid plagiarism: 'The best way… is to change

the audience and to change the purpose. In other words, you say, 'right, write a newspaper' – you know if it's vast reams out of an encyclopaedia' [TC/En]. One teacher employed a strict word limit: on downloaded text [CC/En]. Another example shifted the onus onto pupils to develop their own strategies: 'You have to really explain to them that they need to process the information themselves and just because it's a wonderful print-out with lots of graphics, doesn't really mean anything' [MC/En]. The importance of developing students' critical thinking skills in this age of digital technology has recently been recognised but educators are only now beginning to devise programmes which tackle this issue strategically (as does Koh 2002, for example); detailed guidance is needed here.

The mediating strategies outlined above could be said to describe ways which teachers are developing to 'tame' ICT – in the sense of overcoming potential drawbacks of using it without due care and attention to underlying learning aims. They also describe related pupil strategies which are deliberately fostered in order to meet the same objective of focusing attention away from the distracting nature of sophisticated features of the technology itself and onto intended subject learning. The emerging pedagogic strategies encompass development of both subject-specific and generic information processing skills and these are specified at varying levels of sophistication and detail. As illustrated above, their nature was not always made explicit. In the following section we explore further the new opportunities afforded by using ICT and the degree to which exploiting these is perceived to transform classroom practice.

New forms of subject learning

Several examples illustrate the degree to which using technological tools is actually beginning to play a role in shaping activity, alleviating existing constraints and catalysing changes in subject practice. It was notable that English teachers most frequently pointed to ICT use improving presentation and spelling and facilitating redrafting of written work. It seems that more creative ways of exploiting ICT and in particular, the power and potential of word processing generally remain unrealised in classroom practice (as corroborated by the OECD 2001). However, a few English teachers did perceive the contribution of ICT use as going beyond drafting or presentation issues towards actually changing our notions of writing (cf. Norris *et al.* 1999) so that 'you're never on the final draft' [CC/En]: 'It's something you can mess about with on the screen and improve and delete so that nobody ever needs to see a finished version' [VC/En]. Some imaginative use was described as facilitating manipulation of texts – and hence exploration of language – in new ways. Only in one department though was there a shift towards a clear awareness of how ICT might be exploited further to enhance 'reversioning' (i.e. recasting an existing text for alternative audiences). This was described as 'adding another dimension to one's teaching', helping pupils to see how context is defined and to reflect upon this:

> Just giving them one text and getting them to change nouns and verbs and contextual clues to change it from say being a Victorian Alice in Wonderland to a Western or something and it was definitely a much faster job doing it in the IT room. [SC/En]

Some teachers described how use of ICT – particularly word processing and e-mailing – opens up new modes of communication to explore and serves to change conventions for letter writing:

> It's affecting the way people write to each other using electronic means… We had a unit where we were doing letter writing and children were actually very good at e-mailing each other and we talked about that as another means of communication and, as I say, the idea of looking at the different conventions that exist and the way that that contrasts with, say, formal letter writing is a whole area to look at. [VC/En]

On the whole, however, ICT was perceived as enhancing current practice, rather than transforming it. Our italic emphases in the following excerpt illustrate a perceived lack of impact upon pedagogy of the NC requirements to incorporate use of ICT, even in Technology College, where opportunities for use were most strongly developed:

> Rather than just doing a research project based upon books, magazines, newspapers and so on, they have to, according to the National Curriculum now, include reading texts that are produced on the Internet or CD-ROMS, which is something we do anyway. I don't think it really makes that much difference. We don't have to specifically study something on the CD-ROM or Internet, we just have to make it available to them… I don't think it's making that much of an impingement on what we're doing. [TC/En]

In mathematics too, despite apparently widespread integration of ICT into subject schemes, there was a concern to emphasise continuities in subject practice and thinking:

> We have I think very deliberately not wanted IT to take over in any sense. We still wish to value some of the mathematical basics and so on. It is a subject which isn't necessarily always best taught through IT… So I would still say that a lot of our teaching within our Maths lessons has remained uninfluenced by IT. We're working in our classrooms in fairly traditional ways. [TC/Ma]

At the same time, other (infrequent) comments suggested that tools such as graphic calculators and spreadsheets have made an impact on the subject itself or become permeated throughout teaching of the subject: 'I think it's very difficult to imagine a Maths department who don't use spreadsheets to teach Maths…to, well, investigate basic number sequences, but use them to solve problems as well' [TC/Ma]. Graphing in particular was a key area in which the immediate response, visual representation and dynamic effect afforded by using ICT was described as helping students to access and understand difficult mathematical concepts and relationships in ways which would otherwise be extremely difficult:

> Using Coypu [graphing package]… shows them very easily what altering the equation does to the curve, and that does help them tremendously. / [In] some cases with that it's actually kids who would have drawn a blank on that whole topic actually have a bit of insight. / It's a very, very difficult topic... [TC/Ma]

Science teachers in all departments described how using ICT has allowed teachers and students to observe or interact with simulations, animations or phenomena in novel ways that may be too dangerous or complex for the school laboratory. This represents a degree of transformation of subject practice:

> There's a brilliant CD-ROM… and it's interactive in that you can extract data directly from video clips, which is excellent because they're often events that you could never do in the lab, like the space shuttle taking off. [TC/Sc]

> There's no way you could show how the molecules move... other than looking at the lattice structure; although you can try to draw that on a board, you'll never get that 3-D image perfectly and you can't angle it to then move round, you'd have to have a model, but there's something called 'Chemistry Set' where you can actually move the thing round and rotate it at different angles so that you can see the patterns of the molecules and the atoms. [GS/Sc]

Further examples mentioned included demonstrations of the properties of metals ('so you don't end up blowing yourself up!' [MC/Sc]) and of heat transfer from hot water using a data-logger [SC/Sc]. As in mathematics, the power of vivid, visual representations of this kind was strengthened by its link with developing understanding: '…actually seeing an electron going around a nucleus – they can actually start understanding where the cells are coming from...' [MC/Sc]. The biology simulation described below offers an experience that could not feasibly be achieved in a laboratory context. The account illustrates how a skilful teacher exploits this feature of the simulation, using it as a basis for stimulating questioning of pupils and requiring them to discuss and reflect on the underlying processes in some depth:

> You can actually demonstrate, first of all see a red blood cell squeezing its way through a capillary and see it in action, and you can discuss what is actually happening here, what is it going through… why not just go through the biggest route, what's the reason that the red blood cells have to be routed through these capillaries? What's it doing as you are watching it that you can't see? What's being picked up? What liquid is it in? [TC/Sc]

However, while increasing use of ICT in the laboratory was regarded as more authentic, the results of transformation along these lines are potentially drastic and unwelcome:

> God forbid, but it could almost replace the laboratory… I don't really want to go down that [line] but I think we might find that inevitable… the kids will almost not touch wet Chemistry. But in the real world, it rarely happens – in the University lab most experimentation is done with a computerised machine. [VC/Sc]

Only one Science department spoke explicitly about how ICT might influence teaching and learning approaches:

> If it's to work then we're going to have to change our teaching styles and strategy [to do] a lot less… presentation… I mean [ICT is] chalk and talk in a modern style, in a sense, and hopefully much more effective … But there's much more… pupils could do a lot more independent learning. [VC/Sc]

Finally, both English and Science teachers regarded the information that can be obtained via the Internet as being more up to date and broad-ranging than conventional library resources. This allows pupils to be involved with topical issues, for example researching

the cloning of 'Dolly' the sheep [SC/Sc] or the exploration of outer space [CC/Sc; SC/Sc; TC/Sc].

Further examples similarly characterise the extent to which core subject practices, tools and methods are beginning to adapt and change, but the learning aims and values of these subject cultures seem to remain mostly intact – in line with the core subject curricula. Despite an almost unanimous expression of enthusiasm in the teacher focus groups for using ICT to support subject teaching and learning, we can conclude that there is limited evidence for a fundamental impact on the nature and goals of subject practice. Instead, ICT use serves to broaden reference, reduce laboriousness and increase efficiency, improve pupil motivation and the quality of work, and facilitate learning.

Our findings corroborate those of the literature reviewed earlier which indicated that teachers tend to 'assimilate' use of ICT into existing practices rather than to 'accommodate' in terms of changing their subject content, goals and pedagogies (Kerr 1991, Watson *et al*. 1993, Goodson and Mangan 1995). Similarly, previous research has shown that ICT can be used to support a variety of teaching and learning approaches so that teachers do not need to change their practice (Myhre 1998, Niederhauser and Stoddart 2001). Our findings may also reflect a technocentric view of ICT and the minimal statutory requirements for using it. Consequently, teachers do seem to be using ICT largely to support and enhance existing classroom practice (Myhre 1998, Noss and Pachler 1999).

However, the situation is not as straightforward as this. A gradual process of pedagogical evolution is also evident now as the teacher's role develops to encompass mediating the process of ICT-supported learning. For example, mathematics teachers suggested that technology may play an important part in promoting an 'investigative' approach to developing mathematical ideas, by facilitating more routine elements of such work and so supporting experimentation: 'They're carrying out investigations that it wouldn't be sensible to do with pencil and paper and would just be tedious and repetitious to do with an ordinary calculator' [SC/Ma]. 'They can do more investigative work, can't they. If something doesn't work, then they can try something else. / …You can make tasks more open ended' [GS/Ma]. Teachers suggested that, by helping to create the classroom conditions in which investigations could be conducted successfully, use of technology made this form of classroom activity a more viable option. Such use of technology was enabling them to employ an established form of practice more effectively and extensively. At the same time, however, this and other ways of using technology were giving rise to unanticipated phenomena, such as tinkering by students (Ruthven and Hennessy 2002). The new experiences arising in the course of getting to grips with this powerful new cultural tool for learning, which is itself continually evolving, in turn lead learners to develop new strategies and teachers to start to re-evaluate and modify aspects of their practice and thinking. The nature of the sociocultural system which frames classroom activity thereby begins to shift.

For unanticipated effects of technology use to result in positive change, of course, teachers need to understand the potential educational value of the specific form of technology and be open to developing ways of reaching it (Schofield 1995). The teachers we interviewed were indeed starting to develop their practice in ways which both positively exploited the new opportunities arising and avoided their potential distraction of pupils by maintaining the focus of attention on important subject learning aims. At this point in time, then, teachers who are working towards integrating ICT use recognise the need for new pedagogic strategies and some of them have begun to develop and articulate these.

Subject differences

A relationship between subject and reported levels of integration into schemes of work has emerged from this analysis. To summarise this, the Mathematics interviews yielded the strongest evidence of collective policy making, feelings of pressure to use ICT, least reluctance to use it (discriminately), and ironically, most external restraint. Science teachers were most positive about the educational benefits. Variation was greatest within and between English departments, where cohesive policy on ICT was notably weaker. Generally, less integrated use, less evidence of ICT being visibly used as a tool for learning, and more anxiety and feelings of reluctance to surrender to colonisation by ICT were reported in English. A tension appears to exist for some teachers between the desire to use ICT effectively, and an anxiety that the ways in which ICT has been claimed to enhance teaching, e.g. as a 'tool' to increase speed and productivity, seem to contradict the core values of the subject culture.[vii]

Our findings resembled those of Goodwyn et al. (1997) who found that about half of a sample of English teachers were reluctant to embrace digital technology. Some feared the erosion of the print culture and many had unresolved mixed feelings. We can surmise that the cultural significance of technology as a learning tool is not yet visible within the pedagogy of English (cf. Lave and Wenger 1991). Another potential factor of influence may be that, at this point in time, many schools prioritised access to facilities and use of ICT in other subjects. Lack of opportunity could thus have interacted with lack of a need to think about and develop integrated use of ICT. English teachers may in fact be more disparate in their views concerning ICT use than concerning other pedagogical issues. (Further discussion of subject culture differences in this data is provided by Ruthven *et al*. submitted-a).

Conclusion

The themes emerging from this analysis of teacher perspectives converge to offer a grounded model of the issues surrounding integration of ICT into subject teaching. Links have been made with some salient issues identified in previous research studies, but the

model goes beyond those studies in terms of: the scope of the investigation and its intermediate approach between large-scale surveys and individual case studies; its focus on professional thinking and evolving pedagogic practice, and its context of mainstream schooling in England and the constraints operating there.

The first strand of the model concerns teacher commitment to integrating use of ICT in subject practice. Some facets of this include: recognising the educational value and believing in the transformative potential of the technology (as embodied in the affordances illustrated earlier); integrating ICT into schemes of work and developing consistency in types of use between departmental colleagues; responding to external pressures and constraints arising in the workplace and beyond. The latter include having to make effective use of an impending timetabled session in the computer suite; an appropriate emphasis on teaching technical skills; lack of adequate access to technology, experience and confidence with it; lack of professional control linked to the pressure to conform to centralised curriculum and assessment systems and ICT initiatives. Despite these constraints, the teachers interviewed were generally speaking open rather than resistant to change, and committed to using ICT in the classroom .

A complementary theme concerns caution about some forms of use. While there was a feeling of inevitability and acceptance of the role of technology, teachers simultaneously portrayed a reflective and critical outlook. There was evidence of a conservative approach to harnessing the powerful potential of using ICT to support learning within each of the three core subject cultures, whereby teachers were sensibly building on and extending existing practice, exploiting the new opportunities arising, yet not blindly jumping in. Pedagogic concerns were well articulated and these included: the dangers of uncritical use, the need to use ICT only where it enhances learning compared with other approaches, and potential sabotage of some key aspects of established subject cultures.

Note that our pupil focus group interviews corroborated many of the teachers' views and concerns (see Deaney *et al*. 2003, for details). Pupils similarly perceived that using ICT engaged them more directly in otherwise too difficult and frustrating activities, focusing their attention and enhancing their grasp of underlying concepts and relationships. However, they, like teachers (Ellis 2001, Ofsted 2001), worried that certain ways of using technology could curtail their thinking processes and obscure underlying ideas. (These uses were mostly related to word processing, calculation and graphing.) Some pupils also recognised the missed learning opportunities associated with uncritical downloading of information. In sum, teachers and pupils were united in their desire to protect core elements of conventional subject practice. Olson (1981) pointed out that over-protection of these elements may limit curriculum reform.

A degree of caution by teachers is inevitable as widespread use of ICT is a relatively recent phenomenon within education. The top-down approach which imposes use of ICT in subject teaching and learning (Goodson and Mangan 1995, Olson 2000) may lead to

critical questioning of the value of using ICT instead of a sense of ownership. Work on organisational change shows that for an innovation to have a significant impact requires shared ownership of plans which start by experimenting in small ways and then expand upon success, and for individuals to work out their own meanings (over a realistic time frame). According to Wright (2001), relearning is at the heart of cultural – rather than cosmetic – change. Teachers clearly need to develop their own forms of reflective classroom practice regarding ICT (Scrimshaw 1997) if significant pedagogical change is to take place. Achieving this will be no mean feat. Kirk and MacDonald (2001) highlighted the complex obstacles which teachers face in experiencing ownership of curriculum reform. Adaptation of materials to their local contexts is far more feasible.

The final theme associated with our model of technology integration concerns change in the nature of core subject practice and pedagogy. Broadly, teacher accounts described using ICT both to support, enhance and extend existing classroom practice, and to complement or go beyond established practice. Examples of the former included exploiting technology's role in facilitating an investigative or experimental approach to learning, and accessing a much broader range of information resources. The latter included employing dynamic visual representations to improve student access to difficult underlying mathematical and scientific concepts, and using simulations for interaction with otherwise dangerous or complex phenomena.

Collectively, our findings indicate that subject practices are in a considerable state of flux as they begin to adapt and develop in response to a new cultural tool. While there is little evidence of the transformation of certain fundamental aspects of subject cultures (goals, curricula), the impact here is severely constrained by nationally prescribed curriculum and assessment frameworks. The introduction of these frameworks with no systematic integration of ICT has in practice reinforced the structure of the traditional academic curriculum in England, whose underlying ethos is at odds with the construction of ICT as a cross-curricular 'tool' and a vocational 'key skill' (Selwyn 1999b). This blatant contradiction within educational policy results in a lack of guidance and support for practitioners in incorporating ICT in subject teaching in appropriate ways directly related to the prescribed curriculum.

However a process of 'pedagogical evolution' does appear to be taking place, namely a gradual but perceptible shift in subject practice and thinking, involving both pupils and teachers developing new strategies in response to new experiences and the lifting of existing constraints. Teachers are exploiting the fresh opportunities arising to support pupil learning as ICT itself evolves, and they are helping pupils to reach higher levels of understanding. It is particularly notable that teachers are not merely exploiting the positive affordances of the technology, but are intervening where its mediating role potentially obstructs rather than supports learning (Lave and Wenger 1991). This entails devising pedagogic strategies which maintain the focus of attention on subject matter and learning objectives. Specifically, these strategies included structuring and channelling

activity; directing pupils' attention away from distracting features and superficial concerns and towards target concepts and underlying processes; encouraging pupil reflection and avoiding mechanical forms of ICT use; developing 'critical literacy'. Teachers were thus starting to address the need for developing new pupil skills. To conclude, our evidence shows that despite the imposition of ICT initiatives and the very real internal and external constraints on using it, secondary teachers are rising to the challenge which this powerful tool presents. They were found to be generating, trialling and critically reflecting on some new forms of activity, resources and strategies for mediating ICT-supported subject learning in their classrooms.

This study of teacher perspectives allows us to specify some further aims for successful integration at the level of departmental policy and planning, as follows:

- To offer teachers opportunities for long-term collegial interaction (Carney 1998) involving critical reflection, sharing ideas, and research concerning the use of ICT
- To integrate ICT into schemes of work in ways which satisfy the NC and assist in meeting learning objectives but ensure that use is selective, appropriate and critical
- To take account of – and build up – pupils' and teachers' levels of technological expertise
- To constantly evaluate the unique contribution of ICT and its specific role in enhancing teaching and learning activity
- Consequently, to offer a carefully formulated balance of complementary ICT-supported and other learning activities

The main implications of the interview data for policy at the whole school level include the desirability of building a coherent and supportive community of practice associated with using ICT effectively, regularly and consistently (Dawes 2001). Essential too is offering opportunities for exploration and familiarisation with technology, in order to build teacher confidence and iron out uneven levels of access and experience. This applies to subject departments as well as to individuals; the findings indicate that supportive attitudes alone are insufficient and some degree of organisational change may be needed. It would also be useful to clarify the reasons, departmental responsibilities and mechanisms for integrating ICT into schemes of work. These need to remain open to re-assessment and could include a shared whole school framework for developing pupils' 'critical literacy' skills.

The wider implications entail a shift away from a technologically driven model of ICT integration, towards one based on teacher involvement. This means an emphasis on developing and sharing pedagogic expertise concerning ICT use in subject teaching and learning, and re-evaluating objectives, curricula and assessment. Above all, the rationale underlying ICT initiatives needs to be made clear, and the intricate relationship between

the ensuing curriculum change and pedagogical evolution recognised. 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 ICT (McCormick & Scrimshaw, 2001). It would serve to elevate the role of practitioners in effecting classroom change. In the longer term, we expect ICT use to play a major role in reshaping education, as some of the obstacles identified are overcome and classroom, school and subject communities continue to change their practice in order to exploit ICT more fully.It underestimates the degree of change required in teachers' understanding and beliefs (McCormick & Scrimshaw, 2001).

The second, developmental phase of this project comprised a set of classroom case studies carried out in partnership with teachers researching and developing their own practice. Promising pedagogic strategies were trialled in depth across a range of curriculum subjects. An overarching analysis of this data examines how teachers create the conditions for successfully supporting learning using ICT, charts the development of their practical theories over time, and explores teachers' and pupils' shifting roles in this context (Hennessy *et al*. 2003, Deaney *et al*. in preparation, Ruthven *et al*. submitted-b).

Acknowledgements

Thanks to Rosemary Deaney, Louise Goodwin, Alison Miller and the teacher participants for their various contributions to carrying out this study, and to the Wallenberg Research Centre for Educational Improvement for supporting the research partnership and this particular project.

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[i] The 3 core subjects in the National Curriculum (NC) for England and Wales are statutory until age 16. Attainment in each of these subjects is measured through annual teacher assessment, NC tests at the ages of 7, 11 and 14, and national GCSE examinations at 16. The 9 non-core foundation subjects are statutory until age 14 and not subject to NC testing.

[ii] Previously known as 'information technology', use of ICT was introduced as a cross-curricular skill in the NC for England and Wales well over a decade ago (NCC 1989).

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

[iv] The survey item offered only these two options. The following year, when an intermediate option was added, the profile of responses altered to Substantial ~20%, Some ~-60%, None ~20%.

[v] Hadley and Sheingold, 1993, constructed a similar typology of teachers but the American orientation of the study makes it less resonant with the British situation.

[vi] National requirements for ICT use are more specific in this subject.

[vii] A gender dynamic might possibly be operating here, since English is more of a female culture than the other core subjects. As alluded to earlier, this may impact negatively on teachers' confidence with technology and their perceptions of agency in influencing colleagues to use it. This might be interesting for future research to explore.