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Teacher representations of the successful use of computer-based tools and resources in secondary-school English, mathematics and science

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Abstract

This study investigated professional thinking about pedagogical aspects of technology use in mainstream classroom practice. It focuses on the systems of ideas which frame teacher accounts of the successful use of computer-based tools and resources in the core subjects of English, Mathematics and Science at secondary-school level. These accounts were elicited through group interviews with the relevant subject departments in six secondary schools in England. The analysis identifies seven broad themes in which teachers point to the contribution of technology use in: effecting working processes and improving production; supporting processes of checking, trialling and refinement; enhancing the variety and appeal of classroom activity; fostering pupil independence and peer support; overcoming pupil difficulties and building assurance; broadening reference and increasing currency of activity; and focusing on overarching issues and accentuating important features. Further examination of these themes shows how professional thinking about technology use is anchored in well-established representations of pupil motivation and classroom learning, and how contrasting subject profiles reflect corresponding differences in wider subject cultures.

Keywords: Computer uses in education; Educational technology; Teacher attitude and cognition; Subject teaching and learning; Secondary education; England

1. Introduction

Secondary-school systems world-wide are preoccupied with ‘technology integration’. The term implies extending the use of computers beyond specialist courses and special projects to the everyday practice of mainstream schooling. Much attention has been given to immediate barriers to this aspiration: restricted and inconvenient access to machines; unreliability of equipment and lack of technical support; absence of curriculum-appropriate tools and resources; shortness of lesson duration and pressure of curriculum coverage (Becker, 2000; Cuban, Kirkpatrick, & Peck, 2001). However, the more fundamental challenge is one of integrating computer use into educational practice in fruitful ways. The concern of this study is with practitioner thinking about such aspects of technology integration; its specific focus, the terms in which teachers of core subjects in six English secondary schools consider educational use of computer-based tools and resources to be successful; its guiding spirit, that of Kerr’s (1991, p. 121) admonition that “if technology is to find a place in

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classroom practice, it must be examined in the context of classroom life as teachers live it''.

2. Previous research on teachers' pedagogical perspectives

Research on technology in education has given surprisingly little attention to teachers' pedagogical perspectives, given the central part that they play in classroom technology use.

2.1. Innovative accounts of the contribution of computer use

Earlier large-scale studies of innovative computer use provide incidental evidence about teachers' pedagogical perspectives.

Hadley and Sheingold (1993) surveyed a nationwide sample of US teachers nominated on account of their accomplishment in integrating computers into their teaching. Presented with lists of posited incentives for technology integration, most teachers agreed with ideas of the computer ''becoming a tool for children that works for them in their learning…''; ''providing a means of expanding and applying what has been taught''; and raising motivation by ''helping teachers to make a subject more interesting'' and ''increasing enthusiasm of students for the subjects for which they use the computer'' (p. 280). Likewise, presented with lists of posited changes in their teaching associated with technology integration, teachers gave high ratings to suggestions that they were setting more challenging goals, in terms of being ''better able to present more complex material…''and ''expect[-ing] more from… students in terms of their pursuing and editing their work''; and giving more individual attention, in terms of being ''better able to tailor students' work to their individual needs'' and ''spending more time with individual students'' (p. 276). Drawing on open responses, the study concluded that, for many teachers, ''integrating the computer has turned a teacher-centred classroom into a student-centred one, with the teacher acting more as a coach than information dispenser, and with more collaboration and work in small groups going on'' (p. 277).

Means and Olson (1997) conducted case studies of US innovations nominated as worthy examples of computer use to support project-based curricular activities. Analysis of teachers' reports found that they emphasised change in students' motivation, performance and classroom roles (p. 136). Teachers saw computer use as ''dramatically enhancing student motivation and self-esteem'' (p. x), reflected in increased time on task, willingness to review and revise work, and pride in finished products. Teachers also reported a range of performance benefits beyond development of technical skills, including accomplishment of more complex tasks, increased use of outside information resources, enhanced creativity, improved communication skills, and production of work of higher quality. Finally, teachers reported pupils taking on specialised technical roles in the classroom and providing support for peers and teachers, leading to a more collaborative style in which teachers shifted towards a coaching and advisory role.

Employing different types of design and drawing on multiple informants from a range of settings, these substantial earlier studies indicate that innovating practitioners in the US have seen the main benefits of classroom computer use as being in strengthening the motivation of pupils towards schoolwork; in providing scholastic tools for enlarging pupils' experience and enhancing their performance; and in promoting pupil independence and collaborative working.

2.2. Relations between pedagogical orientation and computer use

More recent studies have sought to relate patterns of computer use to the pedagogical orientation of teachers, conceived in terms of an opposition between a 'constructivist' paradigm and a 'transmission' (Becker, 2000; Ravitz, Becker, & Wong, 2000) or 'didactic' paradigm (Niederhauser & Stoddart, 2001). While theorised as ''representing dramatically different views of teaching and learning [which] give rise to fundamentally different conceptions of the use of computers in instruction'' (Niederhauser & Stoddart, 2001, p. 18), the opposed paradigms have been treated operationally as defining a pedagogical continuum; with correlational techniques employed to reduce more complex patterns of teacher response, and to screen out non-compliant items (Niederhauser & Stoddart, 2001; Ravitz et al., 2000).

While this approach has proved a convenient means of characterising broad relationships between pedagogical orientation and technology integration, it may oversimplify the perspectives and practices of teachers. For example, Niederhauser and Stoddart (2001) found around half of their respondents using both "skill-based transmission" software and "open-ended constructivist" software. Equally, analysis identified teachers who viewed computer use as effective in supporting both "learner-centred construction of knowledge" and "computer-directed transmission of knowledge". The study speculates that these teachers may have been "sophisticated users who chose different types of software to meet specific educational goals", or that they "may simply have used all of the different types of software that were available to them" (p. 28).

2.3. Relations between computer uptake and pedagogical shifts

Further studies have investigated linkages between teachers' uptake of computer use and shifts in their pedagogical approach. Kerr (1991) examined the place of technology in the practice of teachers who were "thoughtful users of technology, but not necessarily the first to try new approaches or the most enthusiastic" (p. 135) in three contrasting US school districts. This study focused on the place of technology in teachers' thinking about their craft. Asked to identify milestones that marked changes in how they thought about teaching, few teachers gave responses which featured technology; and when they did so, it was mentioned as just one factor amongst many (p. 121). It was only in response to more explicit questioning that teachers' ideas about the part played by technology in their teaching were elicited.

Although Kerr noted that "technology may provide more of a fulcrum for classroom change than some of these teachers consciously realized" (p. 131), he pointed to a process of pedagogical change in which teachers' gradual development—and reconstruction—of their perspectives and practices interacts with their adoption of—and adaptation to—new computer uses. More recent studies show how personal and contextual factors are associated with levels and styles of computer use by teachers (Becker, 2000), highlighting how classroom computer use is powerfully mediated by prior practices and routines (Miller & Olson, 1994), and by the interplay of institutional and individual views of student needs and good teaching (Windschitl & Sahl, 2002).

2.4. Influence of school and subject cultures on computer use

Conceptions of teaching and learning, then, are shaped by local cultures, notably those of school and subject. In a Canadian study of the introduction of computer use, Goodson and Mangan (1995) sought to highlight "the challenge which microcomputers in classrooms may present to… subject subcultures" (p. 613). The quantitative element of the study found that, while observed patterns of classroom activity did indeed vary between subject areas, computer use was associated with a common shift towards more individualised activity. The qualitative element of the study found that the dominant trend of teachers' responses to the innovation was one in which "the antecedent subject subculture in effect colonizes the computer, and uses it to teach the existing subject in the existing way" (p. 626). The tension between these two findings calls to mind Kerr's caution that participants may not recognise change—or may minimise it.

Drawing on a nationwide survey, a recent US study related subject specialism to differences in teachers' perspectives on the contribution of computer use to their practice (Becker, Ravitz, & Wong, 1999). Asked to select, from a posited list, the three most important objectives for having students use computers, teachers as a whole placed "finding out about ideas and information" highest (selected by 51 per cent), followed by "expressing self in writing" (44 per cent), then "mastering skills just taught'' (37 per cent) (p. 25). However, there were important variations by subject. Teachers of English were much more likely to select ''expressing self in writing'', less likely to select ''mastering skills just taught'', and also more likely to choose ''presenting information to an audience''. Teachers of Mathematics were much less likely to select ''finding out about ideas and information'' or ''expressing self in writing'', and much more likely to choose ''mastering skills just taught'' and also ''remediation of skills''. Teachers of Science followed the overall profile more closely, but were much more likely to choose ''analyzing information'' as a further important objective of student computer use. Such findings can be interpreted as reflecting established cultures of subject teaching in US secondary schools, where English and Mathematics have been found to represent extremes, with the latter emphasising coverage of standard material in fixed sequence (Stodolsky & Grossman, 1995).

3. Aim and context of the study

The study to be reported here aimed to develop this line of enquiry into teachers' perspectives on successful technology use. Focusing directly on teachers' pedagogical conceptions, adopting a naturalistic approach to eliciting such ideas, and conducted in an educational system where the relatively widespread classroom use of computers has been under-researched, it complements those reviewed above.

This study draws on evidence gathered within a school-university research partnership in which developing the use of computer-based tools and resources to support subject teaching and learning had been identified as a priority across the participating schools. The aim of the opening—formative—phase of the resulting project—conducted over the first half of 2000—was to identify what teachers and pupils[1] saw as successful practice in this area.

[1] Analysis of pupil perspectives has been reported in Deaney, Ruthven, and Hennessy (2003).

3.1. The systemic context of computer use in secondary schools

Government promotion of computer use in English schools started in the early 1980s. Such use became a statutory requirement with the introduction of a National Curriculum in 1989. The main obligation placed on schools was to teach all pupils a new subject aimed at developing capability with Information Technology (IT)—now Information and Communication Technology (ICT)[2]—defined as ''using information sources and IT tools to solve problems [and] to support learning in a variety of contexts'' (Department for Education [DfE], 1995a, p. 1).[3] In line with this second aspect, it was further required that pupils should be given opportunities to develop and apply their ICT capability in other subjects. In turn, the orders for these subjects incorporated ICT requirements or recommendations, although these were rarely substantial or strongly elaborated.[4]

3.2. The influence of national reforms on subject teaching

The introduction of a National Curriculum was part of a programme of educational reform which has had a major impact on secondary schools, particularly in the core subjects of English,

[2] We adopt 'Information and Communication Technology' (ICT), now the more widely used and accepted term.

[3] We refer to the curriculum orders operative at the time when the evidence for this study was gathered.

[4] In English, at secondary level, it was suggested that pupils' critical reading of ''factual and informative texts'' should extend to ''IT-based sources [as well as] printed articles'' (DfE, 1995b: 21); and it was required that pupils' writing should involve ''planning, drafting, redrafting and proofreading their work on paper and on screen'' (DfE, 1995b: 23). Likewise, in Science, the rather general requirement was that pupils ''should be given opportunities to… choose ways of using IT to collect, store, retrieve and present scientific information'' (DfE, 1995c, p. 14). In Mathematics, however, requirements were more extensive and detailed. Technology was to be used to ''explore number patterns'', ''make and interpret tables and graphs of functions'' and ''construct, interpret and evaluate formulae and expressions''; there were requirements ''to use computers to generate and transform graphic images'' and ''produce desired shapes and paths''; and ''as a means to simulate events'' and to ''access required information from… databases'' (DfE, 1995d, p. 13–18).

Mathematics and Science. State-maintained schools have been obliged to follow statutory curriculum orders for each subject, with compliance policed through regular school inspections and further promoted by making public the school-level results of national student assessments. Across the system, the curriculum orders have come to exercise considerable influence on professional practice, and to constitute the main communal point of reference regarding each school subject.

While some schools have responded to the reforms in a literal and mechanical way, Ball and Bowe (1992) also found more autonomous responses in which the new policy texts were 'interpreted' rather than crudely 'implemented'. Equally, Cooper and McIntyre (1996, p. 160) noted the range of existing practice on which these orders drew, suggesting that the reform involved placing "the national seal of approval on… a very catholic collection of ideas of good practice within the subject" and "asking teachers within the subject to adopt each other's good ideas". In effect, these curriculum orders reflect the construction of what might be termed *systemic subject cultures*, and serve to reproduce them.

The reforms have had a particular impact on the organisation and planning of teaching. In English, they have given departments a sense of shared purpose, leading to the production of detailed departmental plans for delivering the curriculum (Cooper & McIntyre, 1996). Equally, departmental schemes of work have become almost universal in Science, ranging from detailed sequences of lesson plans to more flexible outlines (Donnelly, 2000). In both Mathematics and Science departments, such schemes are often organised around commercially produced materials (Ball & Bowe, 1992; Donnelly, 2000; Johnson & Millett, 1996). An indirect effect of the reforms, then, has been to strengthen the co-ordinating function of subject departments within secondary schools, and to increase collegiality within them.

3.3. Characteristics of the participating schools

The state-maintained secondary schools involved in this study were all located within commuting distance of Cambridge. Although some had specialist status (Media College [MC], Sports College [SC], Technology College [TC]), none operated a selective admissions policy. One (Girls' School [GS]) catered only for female pupils, and the final two (Community College [CC], Village College [VC]) were designated simply as neighbourhood schools. Against national norms, however, these schools were relatively socially advantaged and academically successful; ranging from Community College—around the national average in terms of social disadvantage, and somewhat above in academic success—to Sports College —highly favoured in both respects.[5]

In all the participating schools, use of ICT facilities for subject teaching generally depended on gaining access to specially equipped computer classrooms. At best, core subject departments might enjoy some form of timetabled access, but, more commonly, individual teachers had to make opportunistic bookings depending on the availability of a computer room. In Mathematics and Science, however, there were important exceptions to this pattern. Four Mathematics departments [GS; MC; SC; VC] had class sets of graphic calculators which were fairly readily available for use in ordinary classrooms, and two had departmental computer rooms [MC; TC]. Likewise, the teaching laboratories in all Science departments were equipped with data-logging equipment, and one had a departmental computer room [TC].

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 used Logo, and graphing tools, as well as courseware or Internet sites for revision and test preparation. In Science all schools used data logging facilities, multimedia resources and the Internet; and most also reported using spreadsheets, as well as courseware or Internet sites for revision and test preparation.

[5] Fuller information about characteristics of participating schools can be found in Deaney et al. (2003) and Hennessy et al. (2004).

4. Design of the study

A number of considerations influenced the design of this study. Theoretically, it was guided by an orientation which emphasises the social dimension of professional ideas. Pragmatically, it employed research approaches judged conducive to stimulating practitioner reflection as part of a wider programme of school improvement. Given the centrality of collaboration within departments to the development of subject teaching, some form of collective activity was clearly desirable in the formative phase of the project. This included group discussions involving the core subject departments—English, Mathematics and Science—in each of the participating schools.

4.1. Guiding theoretical orientation

This study falls within a tradition of research which seeks to illuminate the thought and discourse of teachers, their knowledge and beliefs, with a view to understanding how they make sense of their professional world (Calderhead, 1996). Such analyses can be conducted at different levels—notably those of person, community or society. Whereas many studies within this tradition have taken a strongly idiographic approach focusing on ‘‘internal frames of reference which are deeply rooted in personal experience’’ (Marland, 1995, p. 131), the primary concern of this study was not with the individual teacher, nor even with the individual department, but with a wider culture; specifically with predominant ideas circulating in the profession. By eliciting and organising constructs current amongst teachers, we envisaged building a model of the substance of this aspect of professional thinking (Brown & McIntyre, 1993).

This, then, is a study of social representations. These are systems of values, ideas and practices which have the dual function of enabling people to construe and master their material and social world, and of providing a code for social exchange amongst the members of a community (Farr & Moscovici, 1984). In particular, Moscovici (1990, pp. 176–177) argues that, in contrast to the parsimony of scholarly theories, social representations are profligate since they involve ‘‘a combination, sometimes deficient and sometimes overabundant, of very different types of thought and information’’; that this distinguishes them ‘‘from specialised or expert knowledge which, [on] the contrary, attempts to follow a single type of thought and to deal with a single category of information’’; so that it is ‘‘normal that representations in a society where so much knowledge is produced and consumed… should be richer than expert theories’’.

This contrast between expert theories and social representations has already been hinted at in reviewing earlier studies which characterised pedagogical positions in strongly differentiated theoretical terms, but actually treated these as the poles of a dispositional continuum to which more complex patterns of teacher response could be reduced. Indeed, the popular appropriation of ‘constructivist’ as a descriptor for teaching practices illustrates exactly the diffusion of meaning which accompanies the passage of a term from expert theory to social representation; and the counterposition of ‘constructivist’ to ‘transmission’ or ‘didactic’ approaches constitutes a contemporary reworking of an older opposition between ‘progressive’ and ‘traditional’ pedagogies.

4.2. Approach to data collection and analysis

Separate focus-group interviews were held with the Mathematics, Science and English departments in each participating school. We selected the subject department as our unit of observation since it is a ‘‘naturally occurring’’ group constituting ‘‘one of the most important contexts in which ideas are formed and decisions made’’ (Kitzinger & Barbour, 1999, p. 9). 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.

The audio-taped sessions were transcribed and segmented into relatively short units of talk. Transcripts were imported into a computer database to facilitate a recursive process of thematic organisation through constant comparison (Glaser

& Strauss, 1967). Over many iterations, this led to the construction of prototypical categories, grouping related material.[6] The goal was to identify well-developed themes running across transcripts. This led to the omission of some marginal ideas which did not meet these conditions, and could not be convincingly assimilated to other themes. While a priori theories were not employed, the data was not taken at face value. Conjectured patterns (e.g., across subject departments) were tested, and alternative interpretations evaluated.

Our approach to data gathering and analysis was devised to identify what features of computer use teachers regarded as successful, and in what ways. However, we are conscious that a casual reading of this analysis of teachers' accounts of *successful* computer use could easily misinterpret it as an overly optimistic—and excessively deterministic—portrayal of computer use *in general*. Had space permitted, we would have interleaved some of the concerns and qualifications volunteered by our informants, so as to discourage such misreading.[7] Equally, we are aware that some readers might want to challenge aspects of our informants' views of success. For the purposes of this study, however, we have endeavoured to avoid an evaluative stance, seeking to respectfully analyse our informants' accounts of what they judged to be successful practice.

5. Major themes emerging from the analysis

Seven major themes emerged from the analysis of these accounts of successful computer use. Each theme points to important ways in which teachers considered that use of ICT tools and resources contributed to classroom practice.

[6] A pilot analysis of mathematics transcripts is reported in Ruthven and Hennessy (2002). In broadening the analysis to cover all the core subjects, the system of codes emerging from this pilot analysis underwent considerable revision and development to reflect the wider range of material involved and to better capture substantial central themes.

[7] Such issues are discussed in Hennessy et al. (2004) as part of a broader examination of teacher perspectives on technology integration.

5.1. Effecting working processes and improving production

Teachers identified a contribution of ICT use to expediting and effecting working processes so increasing the productivity of pupils and the quality of work they produced.

References to the use of ICT for data handling were common in Mathematics and Science:

> We've used spreadsheets… to look at handling data, because they can quickly get tables and produce charts that are much better quality than those that they can produce themselves. [VC/Ma]

> [With] data-logging… you can go straight from raw data to a graph within seconds, whereas with manual methods it takes a lesson to take measurements, and another lesson to draw the graph and analyse it. [TC/Sc]

Teachers emphasised the "speed" or "quickness" of ICT-supported procedures [GS/Ma; MC/Ma; TC/Ma; VC/Ma; TC/Sc; VC/Sc], carried out "within seconds" [TC/Sc;VC/Sc], "directly", "immediately" and "instantly" [TC/Sc], "in a flash" [MC/Ma], leading the computer to be characterised as "an instant tool" [TC/Sc]. Such use of ICT was "time saving" [MC/Ma; TC/Ma; GS/Sc; MC/Sc; VC/Sc] and "kept the pace going" [MC/Ma]. Other comments, particularly in Science, also noted how "precise", "reliable" and "accurate" ICT-supported procedures were [VC/Ma; GS/Sc; SC/Sc; VC/Sc]. In Mathematics, in particular, comments revealed a range of uses of ICT tools in "carrying out investigations that it wouldn't be sensible to do with pencil and paper" [SC/Ma], notably as coursework projects.

In Science, there were occasional references to the use of ICT tools for word processing and desktop publishing, focusing on how "if [pupils] word process they actually produce an almost scientific-looking document" [SC/Sc], so "add[ing] to the quality and pride in the work the pupils have" [TC/Sc]. In English, however, there was extensive comment on the contribution that such tools made to the presentation of pupils' work. Teachers talked of pupils becoming able to produce “industry-quality work” [GS/En] with “a more polished, professional look” [VC/En; similar CC/En]:

> [ICT] has a huge impact… on the presentation. You do get some beautiful work handed in, work that when you sit down it's a pleasure to look at, and it can be a pleasure to read. That's exciting… how professional work can look… but you have to get the quality of work, and when the two come together it's incredibly exciting. [TC/En]

In summary, teachers pointed to ways in which use of ICT could help to expedite and effect working processes—particularly in Mathematics and Science—and to improve the accuracy and appearance of pupils' work—particularly in English.

5.2. Supporting processes of checking, trialling and refinement

Teachers identified a contribution of ICT use to supporting processes of checking, trialling and refinement.

In Mathematics, there was positive comment on courseware which presented sequenced items to pupils, testing them at each step to provide “feedback immediately on how they're doing” [SC/Ma], and “giving the kids a chance to check their work” [CC/Ma]. Equally, there was approval for the use of calculators and spreadsheets to check the results of calculation and graphing already done ‘by hand’ [GS/Ma; VC/Ma]. Such computational tools were also used more interactively to support strategies of problem solving through ‘trial and improvement’ in which conjectured—often estimated—solutions were repeatedly tested and modified accordingly until acceptable [GS/Ma; SC/Ma]. In a related type of activity, a number pattern or graph was preprogrammed and pupils were challenged to “try and spot the rule by choosing different inputs and seeing what the outputs are” [VC/Ma], with the computer enabling pupils to “check [a proposed] rule” [MC/Ma]. Teachers saw such activities as allowing pupils to “do more investigative work” in which “if something doesn't work, then they can try something else” [GS/Ma].

In English, references to the part played by ICT tools in checking and correcting focused on the spell-checking of word-processed work [CC/En; GS/En; TC/En; VC/En]. Such checking was represented as one pole of a spectrum of refinement:

> The computer helps you… in terms of spelling… but then they get into a frame of mind where… this is not a finished thing just because I happen to have got to the last word in the essay, it's actually something I can go back and alter. [CC/En]

Teachers talked of pupils “try[ing] words they wouldn't use otherwise because they know it will be checked” [VC/En] and “playing around” [SC/En; VC/En] with texts by “editing, changing, shifting around” [SC/En], so that a text became “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]. In particular, the easy revisability of drafts “allow [ed pupils] to be much more critical of what they've done” [GS/En], and made it reasonable for teachers to “actually offer some advice for restructuring” [SC/En].

In summary, teachers—primarily in English and Mathematics—pointed to ways in which use of ICT not only helped pupils to check and correct aspects of their work, but supported a style of working in which ideas were tried out and work-in-progress refined.

5.3. Enhancing the variety and appeal of classroom activity

Teachers identified a contribution of ICT use to bringing variety to classroom activity, and enhancing its appeal.

There were references to activity involving ICT use being “something different” [GS/Sc; MC/Sc]; as “mak[ing] a change” [GS/Ma]; as adding “another dimension” [SC/En; GS/Ma; TC/Ma]; as having “novelty value” [GS/En; CC/Ma]; and—most frequently—as providing “variety” [MC/En; CC/Ma; TC/Ma; VC/Ma; CC/Sc; GS/Sc]. Such variety alone was represented as generating pupil interest and motivation:

> The more varied the techniques you can use, like a video, computer, games, they're more interesting to kids because you keep changing the activity…/ The more ways you present something, the more interested they'll be and hopefully you'll keep their interest. [GS/Sc]

Other accounts hinted at further components constituting the 'difference' associated with ICT use:

> It's just a different way, rather than being sat in the classroom…/… It's a quicker way. It's not having to write everything down, and they see it as a privilege to go in and use the computers, so already they're happy, they put more effort in just because it's a change. [MC/Ma]

There was talk of how pupils "like a change from the routine of the classroom situation" and "love to go to the ICT room" [CC/Ma]; of how "going off to the computer [room]… holds their interest, keeps them motivated" [GS/Sc]; and of how "getting them out of the classroom was good" [CC/En]. There were suggestions of pupils "enjoy[ing] seeing things done in a different way" [VC/Ma]; of "a different style of work... going on" [TC/Ma], "a different way of doing things" [MC/Ma], and "a different teaching and learning style" [VC/Ma]. Teachers emphasised the use of ICT tools to make tasks less "laborious" [VC/En; MC/Ma; TC/Sc], less "tedious and repetitious" [SC/Ma]; so eliminating "the drudgery" [SC/Ma], removing "the monotonous stuff" [GS/Sc], and "tak[ing] away the tedium" [VC/Sc]. Reciprocally, working with ICT could take on the character of "playing around" and "messing about" [SC/En; VC/En; GS/Ma; MC/Ma]; it was even dubbed "a motivating toy" [GS/Ma].

Teachers also elaborated how use of ICT could make activities more interesting, exciting and fun, highlighting revision and reinforcement activities in this respect:

> It's very difficult when you're revising to keep it interesting… But use computers and it's… like they've woken up again. [TC/Sc]

> It does get boring, lesson after lesson, going through the tables in the same way, so I set up, on the spreadsheet, part of a multiplication grid, and they had to complete it as quickly as possible. [VC/Ma]

> Using *PowerPoint* to do quizzes… so the question comes up and then they can press and the answer is revealed… is a good way in of reinforcing [detail]… in what to them is a more fun way. [MC/En]

Likewise, in English, editing texts with ICT tools was considered as "adding a little more fun" [TC/En; similar SC/En]. In Science, CD-ROM resources were characterised as "amusing" and "dramatic" as well as "interesting" to pupils [VC/Sc]. In Mathematics, ICT-mediation was seen as making investigations more exciting, while preserving the important intellectual aspect:

> It takes out all the laborious stuff… if you're doing an investigation. It's using it as a tool… to save time, to make it more exciting… but you're still having to do the mathematical stuff yourself. [MC/Ma]

In summary, teachers pointed to ways in which use of ICT could enhance the appeal of classroom activity, not only in terms of novelty and variety, and of fun and excitement, but by reducing the laboriousness of work—related to the effecting of working processes already noted—and introducing a more experimental, playful style—related to the trialling and refinement already noted.

5.4. *Fostering pupil independence and peer support*

In a less developed theme, which must be proposed more tentatively, teachers identified a contribution of ICT use to creating opportunities for pupils to exercise greater independence, share their expertise, and provide mutual support.

Teachers perceived many pupils as having an affinity and confidence with ICT:

> It's a modern tool that children see as being bang up to date and much more theirs… Psychologically they feel that this is their

> territory and they can do things… that we hesitate with. [TC/En]

In a peer culture valorising ICT capability, "kids like to impress each other with what they can do… motivating them to… acquire the skills… [and] to learn more" [CC/En]. Teachers noted how pupils had "shown themselves more self-sufficient than we are at using things like that" [MC/Ma] and valued "their ability to do it by themselves, to learn by themselves" [TC/Sc]. Given the opportunity, pupils could "go off and do amazing things" [GS/En; GS/Ma] so that "it does just feel that you're freeing them to do things that really show their potential" [GS/En].

This was seen to encourage the development of a classroom culture in which pupil expertise with ICT was publicly acknowledged:

> I do deliberately ask them questions and they say "This is how you do it, Sir". You can see that they're really quite pleased with themselves after that. [VC/En]

The wider sharing of such expertise created "all sorts of social networks with people helping each other" [VC/En]. Other departments talked of "much more shared learning" in which pupils "sorted things out as a group" [GS/En]; of how "if you do put people in pairs on the computer, they will actually work collaboratively" producing something "like peer tutoring, which even when you ask for it in certain other lessons you don't get" [CC/En]. One comment saw such sharing of expertise as helping pupils develop more maturity, suggesting that: "some of the people who know quite a lot about using the technology, perhaps haven't had the opportunity to behave in such a responsible way before, and it does move them on" [VC/En].

In summary, teachers—primarily in English—pointed to ways in which use of ICT could create opportunities for pupils to exercise greater independence and responsibility, and to provide peer support through sharing their expertise.

5.5. *Overcoming pupil difficulties and building assurance*

Teachers identified a contribution of ICT use to overcoming difficulties which pupils might encounter in carrying out schoolwork, so removing associated disincentives and building pupils' assurance. Consequently, ICT was described as "a bit of an equaliser kit" [TC/Sc], as "a tremendous motivator for some of the less able pupils" [VC/En], and as making activities "accessible to so many more… not just a chosen few" [TC/En].

ICT tools were seen as alleviating difficulties which many pupils experienced in writing, drawing and graphing by hand. In English, comments referred to how word processing removed "the resistance [from] pupils who are really reticent to produce any written work… because of handwriting issues, spelling issues" [CC/En; similar MC/En; VC/En]. Likewise, in Mathematics, teachers noted how using ICT avoided pupils "doing lots of [hand]writing, which is often something that the lower attainers… are unhappy doing" [SC/Ma; similar MC/Ma], and overcame difficulties in drawing accurate graphs [GS/Ma; VC/Ma]. Most prominently in English, teachers drew attention to the satisfaction and pride which pupils derived from creating "work which is nicely presented" [SC/En], from "produc[ing] something that actually looks really good" [MC/En; similar VC/En], from "submitting something that they're proud of in presentation terms" [GS/En; similar TC/En]. Rather fewer comments on the motivational aspect of improved presentation occurred in Mathematics [VC/Ma] and Science [SC/Sc; TC/Sc].

Teachers also suggested that the directness and immediacy of computer processes helped to build confidence and persistence amongst pupils:

> Lots of them have writing difficulties, lots of them have pen to paper motivational problems, and this gets around all of those and means that they can get straight at it. They can tap, tap, tap and it's there, and they can get feedback immediately on how they're doing. [MC/Ma]
>
> One of the problems that they have is patience and stickability with writing… Developing it

directly on the screen [has] an impact on them in that they are prepared to be patient and determined once they can see immediately in front of them that they can adapt, change, revise… as they go along. [VC/En]

Teachers drew attention not just to the speed and ease with which ICT allowed mistakes to be corrected, but to their subsequent invisibility and impunity:

Some students don't respond well to situations where they make mistakes. Before you know where you are there's a scribble all over their books. But if you're working on a screen then it's just sort of click and then you're off again. [CC/Ma]

They're able to make those changes to their spelling and to their grammar… with me sitting there working with them, and it doesn't seem like a criticism of what they're doing. [TC/En]

In summary, teachers pointed to ways in which use of ICT helped to overcome difficulties encountered by pupils—notably in scribing by hand—and to remove disincentives—notably by producing results immediately, by making correction invisible, and by improving presentation—so building pupils' sense of assurance in carrying out schoolwork.

5.6. Broadening reference and increasing currency of activity

Teachers identified a contribution of ICT use to broadening the range of classroom resources available, and increasing the currency and authenticity of schoolwork.

Teachers appreciated the way in which the Internet "opens up access to… so many more resources" [VC/En], to a "wealth of information" [SC/En; similar SC/Sc], so that "the dimensions of the classroom are a bit broader" [SC/En]. Teachers pointed to pupils accessing "all manner of material" [TC/En], "all sorts of weird and wonderful stuff" [CC/Sc], including "more modern, novel information" [CC/Sc] and material which was "up to date and broad ranging" [VC/En]. They valued the capacity of the Internet to engender a sense of significant contact with wider ideas and opinions:

NASA is a world famous place and it was quite a buzz to be able to ask direct questions. [CC/Sc]

They tend to look at any book we do on Amazon.com, looking for comments… and they bring those in and you get a little bit of interchange of views. [GS/En]

Such contact could provide serendipitous opportunities for wider learning:

Last year… when we were doing cloning, I had a couple of pupils who got onto the Roslin Institute web site—so these are the people who actually cloned the sheep—and found a host of information, not just the science of it, which was perhaps a bit too high-level for them, but also issues about how they'd managed the press release of it. So it actually allowed them to put one scientific event into a far broader context and develop a far wider understanding about the issues of science. [SC/Sc]

Teachers highlighted how CD-ROM material brought "the real thing" into the Science classroom:

Rather than saying right, imagine a red blood cell, imagine it's wiggling through a little tube, it's so different to actually be able to see the real thing in action, in colour, it just gives them a greater experience of what's going on./ The thing about science is that it's a living world, it's everything around us, so you can show them that, you bring it into the classroom and it comes to life. [TC/Sc]

It was now possible to "see things which we can't replicate in the lab" [CC/Sc], such as "some of the experiments... that are too dangerous for them and us to do" [GS/Sc; similar CC/Sc; MC/Sc], or to "extract data directly from video clips… like the space shuttle taking off" [TC/Sc]. Likewise, in English, use of ICT was seen as giving pupils experience of new forms of communication, so conveying how "conventions of letter writing are changing" [CC/En; similar VC/En].

In summary, teachers—primarily in English and Science—pointed to ways in which use of ICT helped to broaden the range and increase the currency of resources accessible in the classroom—giving pupils significant contact with wider ideas—and to enhance the currency and authenticity of schoolwork—by enabling pupils to relate their work more closely to the world beyond the school.

5.7. Focusing on overarching issues and accentuating important features

Teachers identified a contribution of ICT use to focusing attention on overarching issues, and to accentuating important features of situations under consideration.

In Mathematics and Science, ICT could facilitate subsidiary tasks—typically involving routine data handling, calculating and graphing—freeing users to give attention to the substantive issue:

> The key thing about… ICT applications [is] to take away the drudgery out of doing the calculations, so that you can start to access a higher learning point without the problems of making mistakes along the way clouding the issue. [SC/Ma; similar GS/Ma; VC/Ma; TC/Ma; GS/Sc; TC/Sc].

Likewise, computer simulation could avoid pupils "get[ting] bogged down with trying to set up [equipment]" [MC/Sc; similar GS/Sc].

Teachers highlighted how ICT helped "to offer clearer explanations, or visual ones" which pupils accepted "because they'd seen it happening" [MC/Ma]. Relating equations to graphs, for example:

> You can… show them what happens when you start altering the equation… In terms of actually looking at the curve shifting… the immediacy of it actually means that it hangs together better… It's just not better efficiency, but also it is actually sounder for the brain really, if it can see things more immediately. [TC/Ma; similar VC/Ma]

Likewise, graphing data in real time enabled pupils to "see it sort of happening on the screen" [GS/Sc; similar TC/Sc]:

> Where you're actually visualising what's going on in the experiment… is an invaluable use of data-logging. It's taking abstract ideas and actually presenting [pupils] with something which is concrete and visible that they can then make sense of and then relate back to the abstract. They develop a better feel for the whole process. [SC/Sc]

Similarly, computer animations or video presentations allowed pupils to "see how things actually work" [MC/Sc], "to visualise processes that are happening" [SC/Sc]:

> You can actually… see a red blood cell squeezing its way through a capillary… And it gives you something that you can really see in action… It's so different to actually be able to see the real thing in action, in colour. It just gives them a greater experience of what's going on. [TC/Sc]

The interactive, experiential dimensions of some simulations also attracted comment, enabling pupils to "actually move [molecules and the atoms] round" [GS/Sc; similar CC/Sc], or to "go up into a satellite, look down on the world… and experience what it's like, first hand" [TC/Sc].

In English, analogous comments focused on the use of computers for writing. Use of ICT tools for drafting and revising texts enabled pupils to "concentrate on structuring their essay and getting the points in [rather than] being pulled back by poor presentation" [GS/En], helping to "free up their thinking" [SC/En]. Because pupils found "it much easier to alter things" they were more willing to "look[] at their work critically and actually mak[e] changes" [GS/En]. Equally, there were suggestions that working with ICT brought out particular features of texts, "helping with [aspects] like structure, like paragraphing… [which students] can't always see… on the written page" [GS/En].

In summary, teachers—predominantly in Science, then Mathematics—pointed to ways in which use of ICT helped to focus the attention of pupils on overarching issues—notably by effecting subordinate working processes—and to accentuate important features of situations under consideration—notably through vivid representation and clear organisation.

6. Summary and interpretation

This study has investigated professional thinking about pedagogical aspects of technology use in mainstream practice. It has focused on the systems of ideas which frame practitioner accounts of the successful classroom use of computer-based tools and resources in English, Mathematics and Science teaching at secondary school level. This section will summarise the emergent themes and interpret them more broadly.

6.1. Summary of the emergent themes

Our analysis has identified seven major facets of practitioner thinking about the contribution of technology use to teaching and learning, which can be summarised as follows:

- *Effecting working processes and improving production*, notably by increasing the speed and efficiency of routine processes, and improving the accuracy and presentation of work.
- *Supporting processes of checking, trialling and refinement*, notably with respect to checking and correcting basic elements of work, testing and improving problem strategies and solutions, and editing and redrafting written texts.
- *Enhancing the variety and appeal of classroom activity*, notably by providing variety to lessons and altering their ambience, by introducing elements of play, fun and excitement, and reducing the laboriousness of tasks.
- *Fostering pupil independence and peer support*, notably by providing opportunities to share ideas and expertise, and to exercise greater autonomy and responsibility.
- *Overcoming pupil difficulties and building assurance*, notably by alleviating hand writing, drawing and graphing difficulties and easing the resolution of mistakes, so removing disincentives and enhancing pupils' sense of capability and pride in work.
- *Broadening reference and increasing currency of activity*, notably by giving access to diverse up-to-date resources, providing contact with wider ideas, and enhancing the authenticity of tasks.
- *Focusing on overarching issues and accentuating important features*, notably through effecting subordinate tasks, and facilitating the clear organisation and vivid representation of material.

6.2. Interpretation of the emergent themes

In Section 2, our review of the limited evidence from earlier studies suggested that teachers have seen the contribution of computer use as having three broad aspects: in strengthening pupil motivation towards schoolwork; in enhancing scholastic processes and outcomes; and in promoting pupil independence and collaborative working.

In this study, the contribution of technology use to strengthening pupils' motivation was again prominent in teachers' accounts. In view of the more general preoccupation of teachers with maintaining the interest and enthusiasm of their pupils (Brown & McIntyre, 1993), it is not surprising to find this concern running through many of the themes identified here. Our findings illustrate the abundant representations of pupil motivation which professional thinking brings to bear on classroom computer use. Ranging across several of the themes, motivation is variously represented as being strengthened through enhancing the variety of schoolwork, introducing novelty, reducing laboriousness, increasing playfulness, injecting fun, and generating excitement; through increasing the currency and authenticity of classroom activity; through exploiting pupils' affinity for the new, according them recognition, and conferring responsibility on them; and through alleviating pupils' difficulties, removing disincentives, diminishing anxiety, building assurance, and increasing pride. In effect, then, this study shows teachers appropriating new tools and resources to much wider and well-established practitioner representations of pupil motivation.

In this study too, teachers elaborated the contribution of technology use to enhancing scholastic processes and outcomes. Ranging across themes, uses of technology are variously represented as broadening the resources and opportunities available for schoolwork, so enhancing the quality of pupil experience; as expediting and effecting working processes, so increasing the pace of lessons and improving the quantity and quality of pupils' work produced; as assisting pupils to check and correct work, to try out ideas, and to refine work in progress, so improving products and promoting learning; and as providing vivid representations and facilitating the generation and organisation of material, so helping pupils to appreciate overarching issues and key relationships. Again, these themes illustrate how professional thinking about computer use is shaped by concerns with those forms of pupil progress which earlier research has identified as being salient in teacher thinking: coverage of work and creation of products, as well as development of capability (Brown & McIntyre, 1993).

Finally—and in contrast to some earlier studies—relatively little emphasis was found in this study on technology use as promoting pupil independence and collaborative working. Of course, the earlier American studies purposively selected innovative practice and practitioners for investigation, against a background of reform movements advocating such restructuring of classroom activity and reshaping of roles. In England, however, as indicated in Section 3, the emphasis of government-initiated educational reform has been different; indeed official pronouncements on classroom organisation have tended to reassert the importance of teacher-led, whole-class activity in an educational system with longstanding classroom traditions of various forms of individual and group activity, and of project work. Nevertheless, particularly amongst teachers of English, this study did find some valorisation of computer use as promoting forms of pupil independence and collaborative working. This will be discussed further—in the following subsection—in relation to subject differences.

6.3. Interpretation of subject differences

As indicated in Section 5, subject rather than school differences were more salient in the ideas presented in departmental accounts. In forming overarching thematic constructs, our analysis tended to discount such differences, although they were maintained within the fuller characterisation of each theme. Differences of this type have often been treated as indices of differing subject cultures, although previous studies show the difficulty of operationalising this idea in depth (Goodson & Mangan, 1995; Stodolsky & Grossman, 1995), and the danger of neglecting cultural variation within subjects (Ball & Lacey, 1995; Boaler, 1997). However, given the evidence—as reviewed in Section 3—of how national subject orders drew together varied strands of existing professional thinking and practice, and of how these orders have subsequently come to exercise an important normative influence on such thinking and practice, it is clear that—in the English context—these orders provide a valuable reference point in exploring relationships between wider subject cultures—of which they can be taken as institutionalised expressions—and representations of technology use.

There are several features of the orders which differentiate the three core subjects. One small but revealing contrast lies in the stems used to preface specified elements of the curriculum. In brief, only in English (DfE, 1995b) are there—extensive—references to what "pupils should be encouraged" to do; and, while all three orders specify things that "pupils should be given opportunities" to do and that "pupils should be taught", the former usage predominates in English, the latter in Science (DfE, 1995c) and Mathematics (DfE, 1995d). Equally, the English order acknowledges personal and inter-personal dimensions which are absent from the orders in Mathematics and Science. For example, the strands of the English order concerned with reading and writing talk of pupils learning to "articulate informed personal opinions" (p. 21) and to "develop their own distinctive and original styles" (p. 23), and the strand dealing with speaking and listening represents pupils as participating in diverse forms of group activity and classroom communication. In such ways, the English order conveys a much stronger sense of pupil agency and collective activity. This, in turn, provides a plausible cultural explanation for the greater reference by English departments to the contribution of technology use to fostering pupil independence and peer support.

Related to this issue is what an earlier study has described as teachers' rejection of "a mechanistic approach to English as highly reductive, ignoring what they see as key aspects of English… [which] emphasiz[e] the value of pupils' self-exploration and self-expression" (Cooper & McIntyre, 1996, p. 56). In the subject orders, there is undoubtedly more detailed prescription and itemisation of curriculum content in Mathematics, and particularly in Science, than in English. Arguably, this atomisation reflects—and reproduces—a culture of teaching to specific objectives, and generates pressure towards pointwise coverage of material. These may be important factors in the greater concern of Mathematics and Science departments with technology as a means of effecting processes and pacing lessons, and of focusing attention and accentuating features. Conversely, one of our informants noted the emphasis in English on "writing assignments… taking into account audience and purpose" [VC/En]. This emphasis is certainly reflected in the subject order, as is a concern for "final polished work" which is "neat and legible, and makes full use of presentational devices where appropriate" (p. 23). This illuminates the particular concern of English departments with the contribution of technology to the presentation of pupils' work.

A further important difference between the subject orders lies in the treatment of constructive thinking processes, particularly the place of improvisation and adaptation within them. Here, it is the Mathematics order which conveys the strongest sense of a sustained process of—in its own terms—"making and monitoring decisions" through teaching pupils not only to "trial and evaluate a variety of possible approaches" and to "follow and reflect on alternative approaches of their own", but to "find ways of overcoming difficulties which arise" and to "review progress whilst engaging in work" (p. 11). The English order does not convey the same sense of continuous monitoring in talking of teaching pupils "to improve and sustain their writing, developing their competence in planning, drafting, redrafting and proof-reading their work on paper and on screen", but it does envisage review taking place over a more extended time-span, and through more collective mechanisms, by giving pupils opportunities "to analyse critically their own and others' writing" (p. 23). By contrast, the Science order suggests a rather methodical process of "planning experimental procedures", "obtaining evidence", "analysing evidence and drawing conclusions", leading finally to "considering the strength of evidence". Only the first and last of these stages incorporate references to—essentially pre-active—decision making including "carry[ing] out trial runs where appropriate" (p. 15), and essentially post-active evaluation including "consider[ing] improvements to the methods that have been used" (p. 16). This suggests that the limited reference by Science departments to processes of trialling and refinement may be a correlate of tendencies both to pre-structure investigations and to treat writing as a means of recording results rather than forming ideas, reflecting a culture uneasy with 'uncertainty', and a pedagogy correspondingly emphasising coverage of content over development of reasoning (Donnelly, 1999).

A final contrast between the orders lies in the extent to which they acknowledge the contemporary resonance of the subject. In English, such references are extensive, specifying that pupils should read texts which "portray information, issues and events relating to contemporary life" (p. 20) and "from other cultures and traditions that represent their distinctive voices and forms" (p. 19). Equally, there is a concern with language variation in terms of "current influences on spoken and written language", "attitudes to language use" and "standard English and dialectal variations" (p. 18). The Science order identifies some analogous issues in the form of "how applications of science, including those related to health, influence the quality of… life" and "the benefits and drawbacks of scientific and technological developments in environmental and other contexts". In Mathematics, however, there is no explicit recognition of such issues; only a single all-embracing reference to giving pupils opportunities to "use and apply mathematics in practical tasks, in real-life problems and within mathematics itself"

(p. 11), typically realised in the form of 'investigations' in which ''any 'real-life' problems discussed [are] likely to be based around hypothetical situations without implemented solutions'' (Johnson & Millett, 1996, p. 107). This contrast provides a plausible explanation of the lack of expressed concern in Mathematics departments with using technology to broaden the reference and increase the currency of classroom activity; a stance consistent with a predominant view of mathematical activity as independent of any wider social context (Bishop, 1988).

In effect, this analysis shows how subject cultures—notably their pedagogical discourses and practices—shape teacher representations of ICT use, making visible, giving form, and according value to particular issues and approaches. The prominence of pupil agency and collective activity in the culture of English teaching informs the particular attention of English teachers to *Fostering pupil independence and peer support*. Similarly, the predominance of a socially decontextualised view of the subject is reflected in Mathematics teachers' non-attention to *Broadening reference and increasing currency of activity*. Likewise, in Science, a methodical model of subject activity marginalises concern with *Supporting processes of checking, trialling and refinement*.

7. Conclusion

This study has focused more directly than has previous research on practitioner representations of the contribution of computer use to mainstream teaching and learning. It has identified seven themes which encapsulate the main clusters of ideas in the accounts offered by core subject departments in English secondary schools. While the findings show how the substance of professional thinking has expanded to exploit technology use, they also point to important continuities in the terms of that thinking. Conceptions of the contribution of computer-based tools and resources are anchored in well-established practitioner representations of pupil motivation and classroom learning, with contrasting subject profiles reflecting corresponding differences in the wider cultures of subject teaching.

Because of important differences of context, as well as of focus and method, it is not possible to make direct comparisons between the findings of this English study and those of the North American research reviewed in Section 2. While there are suggestive resonances and dissonances, it would be unwise to make too much of them. Instead, more fundamental issues can profitably be signalled. Just as the findings of this study have been shaped by—and must be interpreted in the context of—the systemic reform agenda which has dominated the work of English schools, so previous research in other systems has been shaped by rather different discourses and processes of educational research and reform. In particular, recent studies have often been framed in terms of preconceived idealisations of classroom practice. What this study suggests is that more grounded and situationally adapted concepts may also be needed to achieve the understanding necessary to support practitioners in integrating technology into their classroom practice as part of a ''measured development in their thinking about instruction, their role as teachers, and, most significantly, the look and feel of classrooms as the arenas where education takes place'' (Kerr, 1991, p. 132).

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