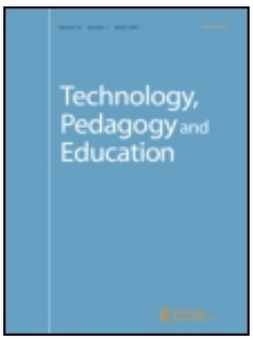

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Developing Successful Pedagogy with Information and Communications Technology: how are science teachers meeting the challenge?

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ABSTRACT From the diversity of views on the role of information and communications technology (ICT) in education, this article focuses on ICT as a tool for enhancing learning in the subject-defined context. Drawing from evidence gathered from teachers' evaluations of over 300 lessons taught using ICT, we examine the implementation strategies and teacher variable factors which define the pedagogy of ICT use and contribute to the frequently reported successful lesson outcomes. Teachers' perception of success was largely expressed in terms of achievement of subject learning objectives and suggested criteria strongly rooted in their pedagogy developed with conventional resources. The role of teachers' beliefs in underpinning their professional practice is examined and the tendency towards conservative teaching styles is discussed.

Introduction

The use of information and communications technology (ICT) in education is widely regarded as a good thing. ICT has a pervasive presence in society for which all participating citizens need appropriate skill. Outside the education profession, advocates of ICT argue its importance as a tool for future life, an investment in careers for individuals and contributing to the future prosperity for the country. Within education, ICT is also seen as a tool for assisting and enhancing learning throughout the curriculum. Less widely appreciated is a view of ICT's potential to change ways of learning. Heppell (1993) has described an evolution of views on the role of ICT in education, beginning with ICT as an object of study in its own right, progressing to a

view of ICT as a replacement teacher, then the view of ICT as an exploratory tool for learning and finally as an agent of pedagogical change. At present, all these views prevail in education and, together with views in society at large, there is confusion over what is valued about ICT and confusion about the motives for promoting ICT. Against this background there is inevitable confusion about how successful practice with ICT might be recognised in schools.

We choose here to argue the case for subject learning; i.e. that, for legitimacy in subject lessons, the purpose for ICT is as a tool for enhancing learning in the subject. Embracing Mortimore's definition of pedagogy as 'any conscious activity by one person designed to enhance learning in another' (Mortimore, 1999, p. 17), we recognise that the introduction of ICT in subject teaching will inevitably have an influence on teachers' pedagogy, since, for most teachers, pedagogy is embedded in the subject context. ICT can only have a valid impact if there is school support in developing operational skills and, arguably, information technology (IT) capability (Loveless, 1995). In England and Wales, the National Curriculum sets objectives both for ICT skills in their own right and as a tool for enhancing teaching and learning in subject studies. The appropriate balance between the two, in terms of school-wide policy, departmental responsibility and schemes of work, is left for schools to interpret and decide.

The recent government teacher training initiative (New Opportunities Fund) to promote the use of ICT in education in England and Wales has focused on subject teaching and has attempted to reinforce the idea of pedagogically appropriate use of ICT in subject teaching. Although the initiative as a whole has disappointed some teachers and policy makers (Office for Standards in Education, 2002), there is no doubt that it has been directly responsible for the infusion of ICT into hundreds of thousands of lessons nationwide. In one training course alone, amongst those available from over 40 training providers, teachers have submitted, so far, evaluation reports on 24,000 science lessons with ICT (reported by the Science Consortium, 2003). A significant feature emerging from our research into the teachers' responses to this particular programme is that the vast majority of participating teachers report successful lessons with ICT. In this article we will consider what the results can teach us about an emerging pedagogy of ICT use and the factors which indicate and influence its development for individual teachers. To achieve this we address three questions:

- What constitutes successful use of ICT in subject teaching?
- What teacher actions contribute towards successful ICT sessions?
- What teacher variables are associated with successful ICT?

The Evidence Base for the Study

Our discussion is based on an analysis of lesson reports submitted by a sample of teachers participating in the training programme provided by the Science Consortium. Although the nature and design of the training programme and its contribution to the perceived success in classrooms are beyond the scope of this article, a brief outline of the course provision will be presented to provide a context for our evidence base.

The training provider was committed to developing the integration and use of ICT in science teaching at the secondary level for ages 11-16. During the scheme (September 1999 to March 2003), it trained science teachers in over 1100 secondary schools. The training programme encouraged teachers to participate in an iterative cycle of reflective teaching in their own classrooms, based on a pre-prepared framework of lessons. The course had six modules, each one looking at a different application or way of using ICT for subject teaching. For each module teachers were required to teach one of their normal classes using ICT, and send in a written evaluation of it. All the necessary materials were provided, including software, lesson plans and worksheets, and, within a particular module, a wide range of topic areas and levels of presentation were available to suit the requirements of a range of pupil groups. Each teacher was individually registered and had online contact with a tutor who gave feedback on their evaluations.

There are few large-scale studies reporting ICT developments in normal classroom teaching, and those that have been done often do not give strong support to gains in pupil learning (Watson, 1993). A recent statistical study from the ImpaCT2 series (Harrison et al, 2002) does show that pupils in schools with high ICT use achieved higher than predicted performance in national tests at ages 14 and 16 years, in comparison with those in schools with low ICT use. These findings reached significance only in science, not in other subjects for this age group, but did not go into any detail of how the ICT was used to result in the higher achievement. The nature of the study precluded consideration of the actual types of ICT activity or teachers' contributions to its manner of use. One problem of research in this area identified by McFarlane (2000) is that of trying to use quantitative data (e.g. improved pupil test scores) to measure what many would claim to be qualitative improvements. The anecdotal finding that pupils understand the subject and engage with the problems posed may not be immediately evident from performance in tests demanding principally memory work. Qualitative studies have been criticised for the small numbers of students involved and the special conditions under which they have been carried out, and meta-analyses of such data have found it difficult to draw conclusions from widely varying contexts.

Against this background, the high frequency of reports of apparent success in our data, together with the fact that the data were representative

of a large-scale exercise in regular classrooms, make the data exceptionally interesting. Although the pro formas for the teachers' evaluations were not specially designed for our study, they provided a unique opportunity to examine a range of factors concerning the implementation, integration and effect of using ICT in subject teaching, as well as considering the changes in teachers' attitudes and behaviour which would indicate a permanent adoption of ICT within their teaching.

The teachers' evaluations were the principal source of data, but we also consulted background school information available through relevant official school inspection reports. A preliminary analysis of the data from a limited number of evaluations was carried out independently by each researcher, using the *NVivo* qualitative analysis tool. The results were compared and discussed and the exercise repeated to determine the extent, limitations and validity of the data. An agreed coding system was then set up and used to analyse the data in a larger sample of evaluations from 61 teachers in science departments in 11 schools, chosen to represent a spread of different types of school and different geographical areas.

What Constitutes Successful Use of ICT in Subject Teaching?

To consider this question, the main problem to address is that of identifying indicators of success with ICT. This is made complicated by the many variables which influence the outcome of ICT in lessons. A significant variable is the diverse readiness of children in classrooms, in terms of their ICT skills (Cuban, 1997). Software design is also clearly a very important factor towards success. The evaluation of software for learning cannot be satisfactorily approached without reference to 'situational' factors which are directly influenced by decisions of teachers as they define lesson objectives and interact with students. Squires & McDougall (1996) argue that the success of software also depends upon the match between the software author's implicit pedagogy and that of the teacher. Evaluation is made further complicated by the fact that often ICT confers advantages which change learning parameters and render tasks with ICT which cannot be directly compared with conventional practice (Hammond, 1994). It appears to be part of the nature of ICT to cause qualitative change to the learning contexts to which it is applied. Noss & Pachler (1999) go as far as to propose that ICT is transforming knowledge and learning to an extent that demands a radical review of present curriculum and methods of teaching and learning.

Since all the teachers involved in our study drew from a common pool of software applications (embracing Internet use, multimedia, data logging, spreadsheets, simulations and presentational tools) carefully chosen by the training provider, the effect of software as a variable is much less significant

in our data set than differences arising from individual teachers in different schools. The teacher is a key variable which we regard as central to our discussion. The use of ICT cannot succeed on its own merits (Kennewell, 2001), but needs the actions of a teacher. Numerous studies have pointed to the importance of the teacher's role in integrating ICT into classroom teaching (Pedretti et al, 1999), the setting of parameters for learning (Scrimshaw, 1997), the definition and management of appropriate learning objectives (Rogers & Wild, 1996), supporting students with procedural strategies (Jessel, 1997; Smith, 1997) and establishing the norms and culture of the classroom (Olson, 1988).

In our study, relying on the self-evaluations of teachers, 83% of their lessons with ICT were rated as having successfully fulfilled their teaching objectives. A simple analysis of these objectives reveals a high profile for subject-related objectives.

Objective type	% of lessons $n = 241$
Subject knowledge and understanding	85
Investigation	14.5
Subject skill or process	12
ICT skill	18.5
Research	8
Revision	4.5

Table I. Types of objectives of lessons.

Clearly, teachers were persuaded of success in terms of the value to their subject teaching rather than the development of ICT skills for their own sake. What factors persuaded teachers of such an impressive level of response?

Gains of quality and efficiency were frequently quoted advantages of ICT use: the speed of access to information, accuracy of data obtained electronically from experiments, speed of calculation of numerical data and the clarity and speed of graphical representation. In the following example, the quality achievable through presentational software appeared to give a boost to the professional self-esteem of the teacher:

> The board work was replaced by the presentation. This gave the lesson a much 'slicker' feel to it and removed the pressure from me to be drawing diagrams as I went along. It also provided more impact, partly because I had imported some images into the presentation but also because it has a more professional appearance. The headings and captions provided a tighter framework for discussion.

This type of example resonates with the officially proclaimed benefits of ICT (Department for Education and Employment, 1999), but, more importantly,

such examples are valuable signals of the recognition by teachers of potential benefits to learning. Goodyear (1985) has argued that ICT has substantially reduced the amount of 'inauthentic' labour inherent in data handling activities. In considering supposed advantages of ICT, one must be cautious that they are more than mere restatements of self-evident properties of software. To say that software works quickly, saves time and offers colourful graphics is merely descriptive of software properties and, as Newton & Rogers (2001) point out, learning benefit only accrues from how such properties are employed. We argue that a teacher's recognition of the potential for learning benefit is an important indicator of successful ICT.

Related to the theme of efficiency, the value of software tools for performing difficult or repetitive tasks is a common theme in teachers' comments. For example, the spreadsheet was widely recognised as a versatile calculating tool with benefits for pupils of all abilities. Here it was acknowledged that most pupils reaped the benefit of the program doing the 'hard' work of multiple calculations, achieving accuracy and reliability in the results, whilst more able pupils in particular were extended by the opportunities for prompt reflection on the results and further exploratory thinking:

> discussion of results became the principal focus of the activity.

Examples like this also illustrate a change in emphasis, reported by many teachers, from the collection of information towards its analysis, facilitating an investigative approach in which students take a large measure of responsibility for designing activities and asking questions about the results. This concurs with the earlier research of Rogers & Wild (1996), who observed in practical science lessons that the use of ICT and an investigative mode of working were mutually beneficial. Investigative methods of working imply a constructivist teaching approach and research has established a strong compatibility between this and ICT tasks. The major study by Sandholtz et al (1997) of the Apple Classrooms of Tomorrow project in the USA demonstrated how ICT transformed classrooms to become more student centred in teaching approach. Smaller-scale studies in the United Kingdom, such as that of Barton (1997), have also indicated high levels of interaction and engagement fostered in ICT tasks. In our own study, many teachers were enthusiastic about the opportunities for students gaining direct control:

> Their learning is increased, as it is the pupils themselves that are able to change the parameters and then see the effect of the change.

> The pupils enjoyed the freedom to choose their own activities and the responsibility that came with it and worked hard all day to produce an excellent set of reports and materials.

Thus we would argue that the development of student-centred teaching approaches is a further indicator of success.

The motivation and enthusiasm of pupils has been a strong theme in evaluation studies (Kirkman, 1993; Cox, 1997) and our study shows no signs of this dimming, even as computers become increasingly pervasive in children's lives. Sandholtz et al (1997) suggest that student enthusiasm is a useful indicator of engagement, along with the extent of voluntary time use, the amount of on-task activity, student initiative and experimentation. All of these factors were indicated in our study, with teachers expressing pleasure with the general quality of engagement of pupils and the high proportion of on-task activity:

> I enjoyed the lessons, as did the pupils judging by their enthusiasm and the written work they produced. Many went far beyond the task.

A striking feature of the data was the high frequency of reports which implied teachers' recognition of ICT making subject knowledge more accessible and improving learning. As previously noted, teachers remarked on the quality of results with data loggers, the labour saving aspects and accuracy and reliability of the recording process, but these software properties were also frequently linked with potential learning gains such as greater clarity of thinking, and encouragement for the interpretation of the results. In particular, real-time data logging, offering the simultaneous presentation of graphs, was seen to be of great value to learning:

> It made it very clear to them what was happening because they could actually see it happen rather than them having to read a thermometer, record a set of results and then plot them as well. It added hugely to the learning value of the lesson in my opinion.

Similarly, simulation software, providing opportunities for performing 'virtual' experiments, was extremely popular amongst teachers, receiving strong recognition for stimulating thought, clarifying ideas, efficient use of time and pupil motivation in general. Teachers liked the flexibility of such software, which gave a variety of opportunities for pupil involvement and often assisted the visualisation of abstract concepts through the imaginative use of interactive animated graphics. In general, the theme of ICT enhancing thinking skills is well supported in research (Underwood & Underwood, 1990; Knight & Knight, 1995; Chisholm & Wetzel, 1998) and our data indicate much teacher satisfaction in the effect of ICT as a facilitator for thinking:

> The fact the results are instantly visible is brilliant because 'what if?' becomes 'yes I was right' or 'no, now why not?' and sends them on a further exploration.

The Internet has become a ubiquitous feature of ICT use and teachers saw this as a valuable and vast source of contemporary information, offering a global perspective of scientific issues. With the use of suggested lesson plans, access was generally easy and rapid and teachers mentioned numerous cases of high-achieving students being extended.

What Teacher Actions Contribute towards Successful ICT Sessions?

Accepting that the teacher has a key role towards the success of ICT, what actions and aspects of that role are needed to realise success? Kennewell has described the teacher as the 'orchestrator' of the influence of ICT on learning in the classroom, bridging the gap between potential and actual activity in lessons (Kennewell, 2001). Loveless et al have argued that the roles of both teachers and learners need to be considered afresh in the new era of the information society brought about by ICT. Ready access to vast amounts of information through ICT has subordinated the role of the teacher as an information provider to one which focuses on how to deal with information in ways which enhance learning (Loveless et al, 2001, pp. 67-72). In part this involves identifying new teaching strategies but it also requires recognition of aspects of skill which do not need to change. If the former pose challenges, the latter should offer reassurance to teachers. It is clear from our study that many established teaching skills not only retain a vital role in classrooms with ICT, but require reassertion in the wake of the additional technical demands of ICT. These involve planning and organisation as well as skills of instruction, communication and intervention.

The importance of clear teaching objectives was a significant message from teachers in our study. In particular, there was strong advocacy of tight definition of tasks involving the use of the Internet. In relation to this, many teachers recognised the delicate balance between the advantages of giving students responsibility and the potential unproductiveness of random 'surfing' on the Internet. Successful solutions often involved limited ranges of website addresses, clear deadlines and encouragement to students to develop their critical skills about the nature and quality of information obtained. In formulating such strategies, some teachers were explicit about being influenced by the perceived ability of their students:

> I would also restrict access to a particular area of a site electronically with weaker students. The process of browsing/surfing detracts from learning with all but the most able.

For all types of ICT activity, Table I shows that by far the majority of stated objectives reflected subject teaching ambitions, with less than one-fifth of

lessons including the development or exercise of ICT skills as an objective. Where there was confusion in the priority of subject or ICT development, lesson outcomes tended to be less satisfactory. Sometimes teachers recognised that ICT offered opportunities for new objectives or widened access to familiar ones:

> ICT provided access to information for those pupils who might otherwise have had difficulties because of SEN [special educational needs], they may have found it difficult to use an index but could use a search engine with ease.

Careful preparation by teachers for lessons with ICT brought due reward. This may seem a trivial observation; however, reports contained a few examples of poor preparation, for reasons which were unclear, but with the inevitable consequence of an unsatisfactory lesson. Our analysis showed the importance of preparation in which teachers not only rehearsed the use of software but considered the skills requirement for the proposed activity and defined tasks to match students' needs. Other issues include choosing the method of starting the lesson (e.g. discussion, theory or demonstration), and designing or adapting worksheets to provide differentiation.

> I prepared a worksheet in advance which contained step by step instructions on how to access the site. I also gave the pupils specific questions to answer in order to reduce browsing. I also allocated a particular planet to each group (3-4 pupils) to avoid information overload.

Teachers' expectations for the manner of engagement of students frequently emphasised thinking and discussion. They often saw an important aspect of their own role in providing a framework for prompting students' thinking; for example, in promoting the 'observe, predict and test' cycle in practical work, in linking or comparing the activity with conventional non-ICT methods or previous learning, or in making comparisons between different sets of information. Indeed, during a practical science experiment, discussion between students and teacher did not interrupt the recording process which proceeded automatically under software control:

> Whilst circulating, I was able to draw individual groups' attention to the emerging graph and to pose questions about what might be happening, thereby guiding them to ideas later expressed during the debriefing session.

Further aspects of teachers' pedagogical skill are decisions about lesson formats and classroom arrangements. Choices they make about whole-class activity, groupwork, or use of the computer suite by individuals, and so on, have a profound effect on the manner of engagement of students. When a

demonstration format was used exclusively, the most commonly declared reasons were logistical constraints: the non-availability of a heavily booked computer suite, or simply the lack of computers or peripheral equipment in sufficient quantity. Teachers were creative in optimising hands-on experience for students through asking them to help with teacher demonstrations, organising them to work through a circus of different activities, or by organising a split class rota. Each organisational format has implications for the interaction between students and teachers and students with each other. All of these organisational devices were in evidence in our study, but, as Table II shows, the type of software used also influenced the choice of teaching format.

Type of activity	Individual (%)	Group (%)	Teacher demonstration (%)
Internet	46	44	10
Data logging	2	33	65
Simulation	19	13	68
Spreadsheet	39	39	22
Using models	30	38	32

Table II. Comparison of teaching formats for different ICT activities (n = 207).

Research has highlighted the value of student collaboration. Indeed, there is clear evidence that working in small groups at the computer is more beneficial to learning than individual use (Underwood & Underwood, 1990, pp. 156-161). Groupwork not only facilitates the sharing of ideas, it provides opportunities for students to explain and have ideas validated as they help each other. These are the conditions for peer tutoring, reported and advocated by Sandholtz et al (1997) for developing a culture which gives students a sense of ownership of the learning process. Our study yielded an example of a teacher deliberately exploiting this mode of working as a method of learning:

> one pupil was able to explain to their partner what they were doing and why. This was in evidence early in the lesson, so I decided to encourage this and to introduce it to other groups; a couple of pupils were surprisingly effective in this role and were obviously empowered by the activity.

Such implicit acknowledgement of students' expertise and the encouragement of mutual help can have a profound positive effect on the motivation and achievement of students (Sandholtz et al, 1997). It has been further observed that when teachers overtly learn alongside and from 'expert' students, the process of integrating the use of ICT into classroom settings gathers pace (Hruskocy et al, 2000). The nature of students'

expertise with computers is worth considering a little; for most student experts, their skill tends to be of an operational and technical kind which is qualitatively different from and complementary to the subject-related skills of the teacher. So, far from being rendered redundant by student expertise, the teacher still retains an important pedagogical role. Loveless et al (2001) have suggested that constructing knowledge from information requires more than the ability to use a variety of ICT techniques but also embraces an ability to question, access, interpret, amend and analyse information (Loveless et al, 2001, p. 67). This in essence is the concept of 'IT capability' and the teacher should be in a strong position to take a lead in helping students to develop this broader skill.

Although research gives strong advocacy to groupwork with computers, studies also indicate caution about the conditions which favour success. In particular, groups must have the ability to organise themselves in ways which integrate the contributions of all members. This demands a certain maturity in students managing the task requirements and resources on their own and the social skills to share and negotiate ideas and roles (Hoyles et al, 1994). Here again there is an important role for teachers, both in structuring the tasks and in organising and managing productive groupings. This is a familiar requirement to teachers, as represented in this example:

> The children worked in pairs chosen by me with the intentions that their working habits and skills would be complementary.

Further affirmation of familiar teaching skills comes from the frequent references in teachers' reports to making links with previous work, setting targets, giving instructions, deciding when to intervene, giving the right sort and amount of help, prompting discussion, asking questions to probe understanding, sharing ideas, issuing reminders and summarising what has been learned, and so on. It is also evident that ICT provided opportunities for enhancing such skills. For example, in giving instructions, it was still necessary to do this orally or with a whiteboard, overhead projector or worksheet, but it was also possible to use *PowerPoint* or web pages with direct hyperlinks to further resources. Teachers report creative ways in using the 'time bonus' of software; giving additional help to weaker pupils, sharing results, prompting analysis and discussion, and generally emphasising thinking about the interpretation of results.

> The use of a model allowed me to spend more time, with the weaker student, whilst those that had a good understanding could extend their knowledge by exploring new situations.

What Teacher Variables are Associated with Successful ICT?

Mumtaz (2000) has observed that the teacher is one of three interlocking factors that influence teachers' use of ICT, along with the institution and resources. Here we shall explore those individual variables which inform teachers' attitudes towards ICT and the choices that they make about their methodology in the classroom. We believe that our data offer glimpses of teachers' beliefs through studying their opinions and choices. We can also observe connections between variables but will be cautious about drawing conclusions about causal relationships.

Teachers' Beliefs

Recognising that teachers carry frontline responsibility for classroom practice, it is fair to begin our discussion by empathising with their viewpoint. Experienced teachers have well-established beliefs about what constitutes successful lessons and learning and they are entitled to ask what ICT contributes to enhance the quality of lessons and learning (Cuban, 1997). When teachers appear not to embrace the vision of ICT, there is likely to be a variety of explanations.

Rejection is sometimes the inevitable result of lack of teacher time for learning how to use ICT or the lack of supporting networks in schools for teachers with low confidence in their ICT skills (Dupagne & Krendl, 1992; Winnans & Brown, 1992; Rosen & Weil, 1995). Dawes (1999) argues that teachers make rational choices in terms of their beliefs and that poor uptake is due to ICT not being 'selected' as much as advocates of new technology would hope.

The manifestation of teachers' beliefs about learning is to be found in a range of attributes and actions observable in everyday professional practice. In each case, teachers' beliefs are implicit in their attitudes, preferences and choices:

- Expectations and beliefs about pupils' abilities (What are appropriate levels of conceptual demand, pace and language? Should students be organised in mixed-ability groupings or setted in order of ability?).
- Choice of objectives when designing tasks (What is the balance of emphasis between process skills and subject content?).
- Assumptions about the teacher's role in the classroom (Is the teacher a knowledge provider or a facilitator, interpreter and guide?).
- Teaching style (Is this characterised as didactic [telling] or investigative [finding out]? How much teacher–student interaction is used? Does questioning technique empathise with students' view?).
- Management style (What principles underpin control and discipline: rules, flexibility, student autonomy, recognition of student expertise?).

- Teaching format (When should students work individually, in small groups or be taught as a whole class?).

In the context of the classroom, a teacher's personal pedagogy may be thought of as a synthesis of their positions on each of these issues.

As our discussion explores the connection between pedagogy and ICT, it must recognise the need to acknowledge the roles of culture, beliefs, representations of subject knowledge, learning environment and interactions between learners and teachers (Loveless et al, 2001, p. 67). The study of teachers' use of ICT by Moseley & Higgins (1999) has established significant connections with their subject knowledge and pedagogy. For example, those with belief in pupil empowerment tended to use small-group work and easily adapted this approach to teaching with ICT. They provided good ICT opportunities for their pupils in both quantity and quality. Teachers who preferred whole-class teaching often did not have such advanced personal skills and confidence in ICT. They saw computer work as an opportunity for pupils to work individually, but did not value this greatly. They made fewer opportunities for pupils to use ICT, and tended to use less complex software (Moseley & Higgins, 1999).

Teaching Styles

In our study, the teaching materials available to teachers could be used in a number of different teaching formats. Most programs could be demonstrated to the whole class, particularly when the school had a data projector or interactive whiteboard. Similarly, most applications could be used by small groups, or by individuals, if the schools had sufficient facilities. Many teachers showed a preference either for whole-class teaching or for small-group work in most of their lessons. Sometimes this was constrained in practice by the computing facilities available at the time of their lessons, but usually teachers clearly stated when this was the case:

> If a computer room had been available then I do think the pupils would have got more out of it.

> ideally I would have liked the pupils to have attempted the activity in small groups on their own machines, but timetabling did not allow this to happen.

The teachers who showed a preference for whole-class teaching generally chose to use a demonstration technique with software. Such lessons were often very successful, particularly with the visualisation software simulating scientific phenomena, when the teachers could feel in control of the pace of the lesson. However, when the same teachers allowed students to use computers, usually for the information gathering tasks, as with the study of

Moseley & Higgins (1999), they tended to set students working individually, rather than in pairs or small groups. This was less successful when many individuals required technical assistance at the same time:

> Not all can log on and be served quickly therefore some students found connection very slow.

Many teachers learned to accommodate their teaching styles to make the best use of the facilities available. Several teachers in well-equipped departments developed a hybrid approach, introducing the software and subject matter to the pupils through demonstration, then allowing them to work in small groups or individually with worksheets, to develop their own understanding.

In our previous discussion of teachers' actions contributing to successful ICT lessons, we noted the desire of many teachers to encourage students to think and their welcome of increased opportunities afforded in software for promoting thinking. Associated with this was the value placed on the role of discussion in helping students gain understanding:

> The model (using just the data projector) allowed for good whole class discussion as the simulation occurred – lots of thinking on feet for us all!

> Pupils were easy to engage in conversation about a dry science topic because they wanted to make the simulation work. This small group discussion is a powerful teaching method and not that easy to achieve.

Investigative approaches were implied in many teachers' descriptions of student activity and teacher interventions:

> Pupils are able to investigate a wider range of questions in a shorter period of time. Their AT 1 [investigation] skills are improved, allowing them to think more independently.

These examples serve to illustrate teachers' engagement with process skills which, according to Scrimshaw (1997), need to be made central elements of a successful curriculum with ICT.

For most experienced teachers, their beliefs about learning and consequent pedagogy are well established before involvement with ICT. A stable equilibrium exists in which the prevailing curriculum, familiar teaching tools and teachers' beliefs refined through experience inform their teaching methods. However, the introduction of new tools, such as those provided by ICT, challenges their existing beliefs (Finlayson & Perry, 1995) and poses questions about their methodology (Solomon, 1986). When a teacher innovates with a new teaching tool, it is natural to adapt its use to the old methods. From the perspective of maintaining self-esteem, teachers

are likely to adopt strategies which either preserve or enhance their role, but if the new tool threatens their influence, they will adopt protective practices which unfortunately can also limit the potential of ICT (Olson, 1981).

Conclusions

For the majority of teachers in our sample, successful ICT was clearly rated in terms of subject teaching objectives: more than four-fifths of lesson evaluations explicitly indicated teachers' satisfaction that lesson objectives were fulfilled. Table III summarises their views on these successful outcomes and the roles they played in achieving them.

Successful outcomes reported by teachers	Number of reports
Lesson objectives successfully achieved	83% (n = 244)
Views on advantages of ICT	n = 218
Potential for clarifying subject matter and promoting thinking	70%
Saves time and labour	51%
Greater ease of use over traditional methods	31%
Potential for improved quality of students' work	23%
Scope for special stimulus to students both of high and low ability	17%
Teachers' role	n = 213
Plenary role with the whole class, demonstrating software, giving instructions or making links between activities and previous knowledge	42%
Circulating around the class, giving subject-related help, guidance and support according to need	42%
Asking questions, prompting discussion and probing students' thinking	38%
Technical troubleshooting and ICT operational help	12%
Students' responses and achievements	n = 244
Good understanding of and thinking about the subject matter	41%
Enjoyment, interest and motivation	38%
Extending the most able and supporting the least able	18%

Table III. Teachers' views on successful outcomes of lessons.

Only one in six reports indicated negative effects on students' achievements. The motivational effect of ICT is likely to have been a persuading factor towards teachers' feelings of success in lessons and in general the character of their comments about students' achievements indicated criteria which were essentially rooted in their existing pedagogy.

We have argued that a teacher's recognition of the potential for learning benefit is an important indicator of successful ICT. This was indicated, not only in teachers' perceptions of students' achievements, but also in their views expressed on the advantages of ICT exemplified in their reported lessons or as visions for future lessons. It should be noted that the pro forma used for teachers' evaluations avoided prompting specific issues for mention as advantages or disadvantages. Teachers' ideas arose in a voluntary manner, thus the results reflect their own values and concerns. It is significant that the topics of concern are strongly focused on teaching and learning. A high frequency of reports implied teachers' recognition that ICT made subject knowledge more accessible, stimulated thought and improved learning. Even the references to time saving frequently stressed pedagogical benefits such as the stimulus of instant response, the reduction of inauthentic labour and the scope for discussion, interpretation and differentiated help.

Our previous discussion examined the importance of the role of the teacher in influencing the outcomes of lessons with ICT and portrayed a range of valuable teacher interventions. The incidence of technical troubleshooting and ICT operational help was relatively low, occurring in less than one-eighth of reports. Taken as a whole, the data show that teachers had a strong organising presence in the classroom, establishing attitudes, defining tasks, selecting lesson formats, setting targets, monitoring progress and so on. These teacher actions appear to be just as necessary for nurturing the success of ICT as they are in conventional situations.

For the majority of teachers, success with ICT was founded on adapting the use of ICT tools to match their existing pedagogy. As Table II shows, teacher demonstration, groupwork and individual work are each well represented as teaching strategies, suggesting a partial but good presence of student-centred methods. Further research should seek to identify innovation in teaching methodology prompted by the unique features of software.

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