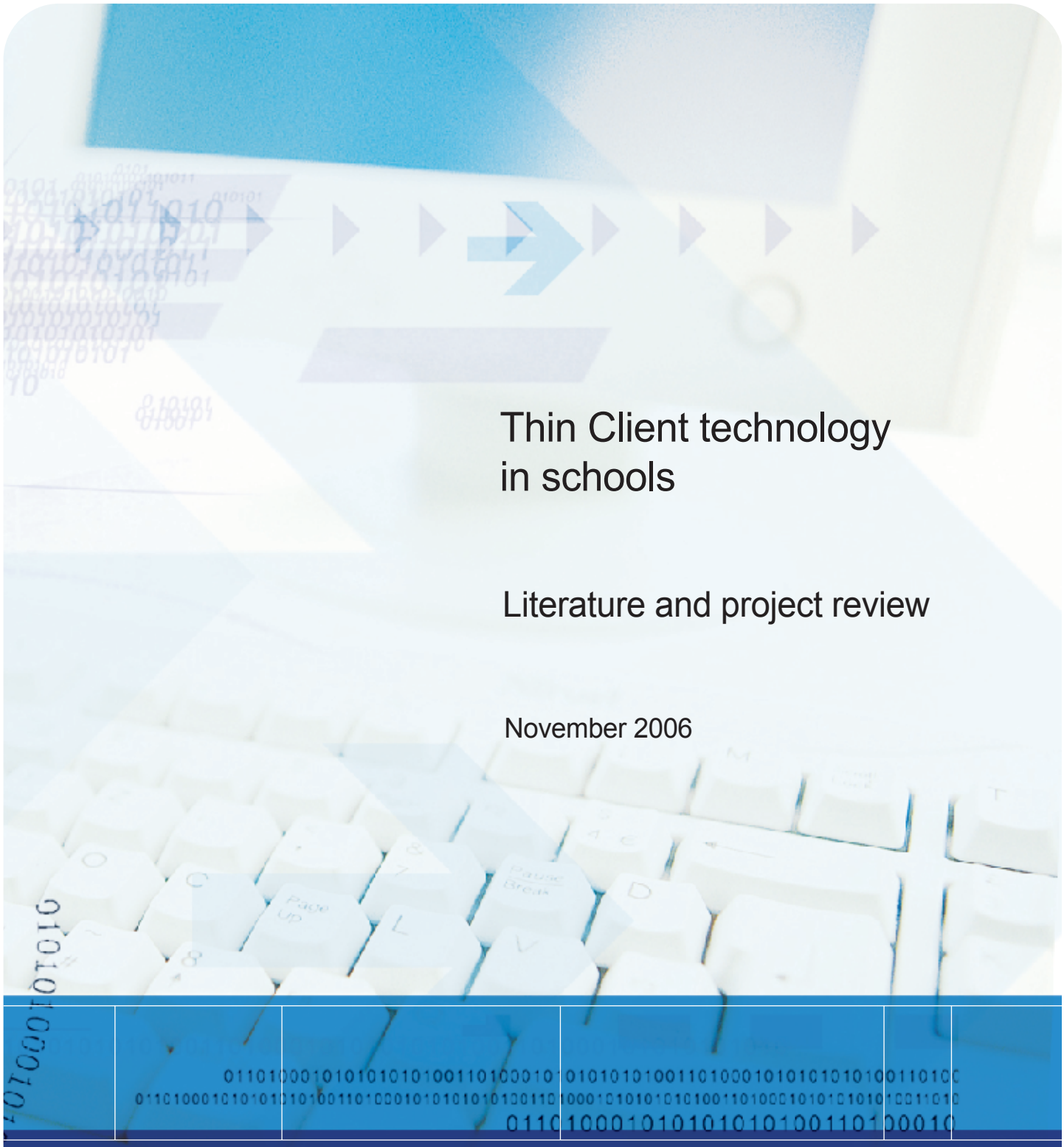

Thin Client technology in schools

Literature and project review

November 2006

Becta Research

Contents

1 Executive summary

This report includes a literature review of Thin Client technology in education and the results of a fact-finding questionnaire to 50 schools using the technology. A second report analyses 12 case studies of schools using Thin Client technology and examines the functionality, benefits and issues in more detail. It also compares the Total Cost of Ownership with comparable schools making use of ICT over Fat Client networks.

A broad definition of Thin Client technology was used in both elements of this report (definitions are given in Section 2.3). Essentially, where either the published literature or a school considered that they were implementing a Thin Client solution, this has been taken at face value. The researchers are confident in this approach. In particular, the project review involved gathering detailed information from schools on the solutions in place.

Key Findings

The researchers identified 133 educational institutions that were using Thin Client networks, though there are likely to be many more across the country. Some 50 of these 133 schools provided detailed information about their solution and experiences.

Within these 50 responses, Thin Client technology was relatively evenly spread between primary and secondary schools. A small minority of the schools in the sample survey (4%) had removed Thin Client networks, due to various difficulties with implementation of the network. However, the vast majority had either implemented their network successfully (72%) or had plans for further extension (6%). This suggests that the majority of schools are satisfied with their solution.

A total of 68% of schools reported that costs had reduced (and only 8% reported that costs had increased) as a result of introducing the Thin Client network. Many schools (30%) had made use of legacy computers on their Thin Client networks, though a large number (42%) had switched completely to bespoke Thin Client terminals. The remaining schools (28%) had a combination of legacy and Thin Client terminals running on their Thin Client networks. See Table 1 below. This shows that whilst a third of schools used legacy equipment (and for these schools that was a great advantage), many other schools did not consider it a priority to keep legacy equipment when switching to Thin Client technology, possibly because of the low cost per terminal for Thin Client technology. Although many schools had Fat Client networks as well on which PCs were used.

Nearly three quarters (74%) of schools in the sample used a hybrid network, offering a mixture of Thin and Fat Client solutions across their school networks. The type of solution in place varied considerably. This shows that many schools may be reluctant to switch across wholesale to Thin Client solutions, partly because of the limitations of this type of solution, summarised below.

Table 1 - Summary of network configurations and terminal types in the schools

Types of terminals on the networks	Percentage of schools	Types of networks used in the school	Percentage of schools
Thin Client networks with only legacy computers (terminals)	30%	Thin Client and Fat Client networks in the school	74%
Thin Client networks with Thin Client terminals	42%	Thin Client network in school	26%
Thin Client networks with both legacy and Thin Client terminals	28%		

Most schools responding (84%) used the Thin Client network for curriculum purposes. A smaller number (36%) also used it for administration. 54% of schools used their Fat Client network for administration as well as for the curriculum. Further research is needed to understand why some of schools reported keeping their administrative networks running on a separate Fat Client network, although some of these explained that it was a requirement of the local authority.

A small number of schools (12%) reported some technical problems with the servers, though on closer examination, some of these problems may be because of poor implementation of the solution. The vast majority of schools thought that their servers were very reliable. Levels of satisfaction are even higher for reliability of the Thin Client terminals.

Advantages and disadvantages

Not all the issues associated with Thin Client technology are unique to this solution; many benefits may also be attributed to well managed Fat Client solutions and many issues are also found in Fat Client solutions that are not well managed.

Advantages and disadvantages found in this research have been broken down below and cover: teaching and learning; costs; management and administration; widening access; rationalisation and sustainability; reliability; security; size; noise and heat; speed and staff training and acceptance. A more detailed analysis is given in Section 5. Key points are listed here.

Teaching and learning

Advantages:

- Uniformity: Thin Clients were easier for teachers to use because every terminal presents the same desktop and user interface, increasing teachers' confidence in using ICT once they had learnt how to use their terminal.
- Improved file sharing: there was less work involved in setting up the resources teachers needed for lessons because this had all been done centrally; it was also more reliable than with Fat Client networks.
- Greater reliability of ICT resources: teachers were more willing to plan and use ICT in their lessons because they were confident that the network and the terminals would be working when they needed to use them.

- Greater access: students had more opportunities to work on projects once the lesson had finished because the number of terminals in general was greater and situated in more locations due to the ability to put in place more terminals for the same budget.

Disadvantages:

- Some software limitations: the type of software being used was largely limited to that able to run on the main server and not necessarily the most suitable for individual teaching and learning needs.

- Graphic intensive requirements: there is evidence that there are problems in running more graphically challenging software such as that requiring video output, or fast moving animation.

- Less flexibility: 12% of schools reported difficulty with access to local peripherals and storage systems. In addition, because of uniform provision, teachers may be less able to find ways of using ICT to suit their particular needs and the needs of their students.

- Split networks: as noted above, some schools reported having a separate administrative Fat Client network. This restricted teachers' access to administrative data from their Thin Client terminal.

Cost

Advantages:

- Reduced cost: 68% of schools in the project review reported that the Thin Client solution had reduced their costs. This is in part because Thin Client workstations (terminals) were cheaper to purchase than PCs.

- Use of legacy equipment: 30% of schools in the project review used legacy kit on their network, showing that they are able to gain value from machines that otherwise might be made obsolete.

- Reduced support and maintenance: 66% of schools reported that Thin Clients needed very little maintenance and technicians could even be shared across sites and institutions.

Disadvantages:

- Increased licensing expenditure: expenditure on software licences can be high with the larger number of workstations, but is no higher than a similar Fat Client network.

- Reliance on the network: even though Thin Client servers proved to be very reliable, if the servers do go down there can be indirect costs caused by having to reschedule lessons, find alternative teaching resources or cope with other disruptions caused by the network failure.

Ease of management, administration and support

Advantages:

- Ease of support: with basic terminals and software being run centrally, it is much easier to sort out problems. Hence, 58% of schools reported greater control and a more reliable service compared with their previous Fat Client solution. It should be simpler to provide the clients with up-to-date software because installations and updates only need implementing on the server.

- Version control: Thin Client networks prevent users storing different versions on local PCs. This can make it easier for the teacher to ensure that all users are using the same version. (If local disk drives are locked down on a Fat Client network, or shared network drives are used, this benefit may also be true of Fat Client networks.)

- Data integrity and security: this may also be improved because the data is stored on the server rather than on a local hard drive which is harder to back up. This benefit is also true of Fat Client networks where storage is restricted to the file servers.

Disadvantages:

- Back-up: the amount of time to back up all the software can be considerable (see for example Correia and Forman, 1998). However, this needs to be set against more complex back-up requirements of Fat Client networks, where on some systems individual machines may hold software and data.

- Licensing: 4% of schools have reported that there can be substantial problems with licensing arrangements depending upon the number of active current users (which is exacerbated if more terminals are in place, though not unique to Thin Client networks).

Widening access

Advantages:

- Greater home access: there are still many homes in developed countries where there is no access to ICT (Vaiol, 2004), and many households in the UK still do not have a PC. As terminals cost less and are easier to support, some 32% of schools have been able to provide low-cost ICT resources to teachers and learners who previously had no access to ICT.

- Greater in-school access: lower terminal costs enable schools to increase the number of terminals, providing greater opportunities for teachers and pupils to use ICT in more lessons, for individual study and in other school areas for tutorials and project work. Similarly, greater provision provides schools with more opportunities for after-school clubs.

Disadvantage:

- Software limitations: 4% of schools reported that the range of educational software may be more limited than what was previously available on PCs (though this depends on the nature of the solution and the school's approach to software procurement).

Rationalisation and sustainability

Advantages:

- Uniformity: a uniform system with a standardisation of terminals, desktops and applications enables users to work confidently in any location.
- Energy saving: Thin Clients are able to use less power than Fat Clients, because the terminals have fewer parts and do less work.
- Sustainability: the use of legacy machines as Thin Client terminals was reported as a benefit (reduced cost) in 10% of schools.

Disadvantage:

- Less diversity: if a school does not keep the software it had previously on its Fat Client architecture, there can be less diversity of ICT resources and therefore fewer opportunities for new and exciting teaching and learning experiences. This limitation was overcome to some extent with many of the schools by either having the older software loaded onto the main Thin Client server as well as new purchases, or by maintaining a hybrid system with the older PCs keeping some of their Fat Client facilities and the software loaded and run locally.

Reliability

Advantages:

- Reliable servers and clients: over 80% of schools in our project review reported reliable servers and clients.
- Ease of replacement: where schools reported terminals failing, they also noted that it was easy to replace them as stocks of replacement terminals were kept on site (possible due to the low cost of terminals).

Disadvantage:

- Split networks: fear of the Thin Client system failing meant that some schools reported keeping a separate Fat Client network for administrative network purposes only, to ensure it could still be used if the Thin Client network went down. This could prevent teachers from accessing administrative data from their Thin Client terminal (which is also a disadvantage for teaching and learning).

Security

Advantages:

- Reduced threat from viruses and malicious activity: because software can be managed centrally and patches and updates can be carried out on the whole system via the central servers, virus protection can be managed more closely and the threat of viruses is reduced. In addition, because Thin Client terminals are locked down by default with no local storage, there is little risk of viruses entering the system through individual Thin Client terminals.
- Lower risk of theft: terminals are less valuable and less conspicuous, they may therefore be less prone to theft (though schools may still need to secure terminals to prevent theft, so this point is arguable).

Other advantages and disadvantages

Advantages:

- Smaller terminals: Thin Client terminals can be smaller than conventional PCs and can therefore fit into classrooms where space is at a premium.

- Less noise, heat and energy: 4% of schools reported that Thin Client terminals are quieter and generate less heat than PCs and laptops; an important consideration in managing the classroom environment. Thin Client terminals also generally use less power than Fat Client PCs.

- Speed of network: whilst several schools in the project review reported slow network speed at times, two thought that the network was faster. Further research would be needed to investigate in detail whether network speeds are favourable over a Thin Client network, and the circumstances in which they are not.

Disadvantages:

- Training in the new system: though it is true of any new installation, switching to Thin Client requires some staff training in the new system, for which time needs to be set aside.

- Securing staff acceptance: one school experienced difficulties in getting management and staff to 'buy into' the Thin Client technology, as these users found it difficult to comprehend the constraints such a system may have on software and external hardware.

- Laptops and logging in: an institution running a Thin Client network may wish to have Fat Client laptops for use offline. Becta (2005b) suggests these could run a ‘terminal emulation’ program to act as a Thin Client whilst on the network. However, Becta also points out that this can lead to user confusion as the user may require a different log-in procedure depending on whether the device is connected to the network or not, and therefore care must be taken to ensure that users understand the log-on procedures required.

2 Background Rationale

Most schools now have extensive information and communication technology (ICT) in place. The cost of supporting, upgrading and replacing this equipment to provide a robust infrastructure for teaching and learning is increasingly onerous. This brings into question whether alternative network architectures, such as Thin Client, could provide the required level of functionality with lower long term costs and/or other benefits.

Some schools have already adopted Thin Client networks (the researchers identified 133 though Becta's *Survey of LAN infrastructure and ICT equipment in schools* (Becta, 2006a) suggests that there are many more – 5.2% of primary schools in that survey were implementing a Thin Client network and 9.2% of secondary schools). There has been no comprehensive study of the capabilities and appropriateness of such systems in education.

This research is broken into two reports, of which this is the first:

- Report 1 (this publication): a review of the research literature and existing projects relating to the use of Thin Client technology in schools; and
- Report 2: a review of twelve schools currently implementing Thin Client technology, together with a comparison of Thin Client Total Cost of Ownership with the Total Cost of Ownership in schools with no Thin Client network in place.

The ultimate aims for the two reports are to:

- provide insights into the functionality, benefits, issues and total costs of ownership for Thin Client technology for the benefit of policy makers and education professionals;
- identify the key educational benefits and concerns which would be influenced by the use of Thin Client technology and have implications for national and government policies; and
- allow schools to make informed decisions both directly through published reports and indirectly through informing Becta's advice to schools.

2.1 Scope

The original aim of the research was to focus on schools in England and relevant published evaluation reports and academic articles about the current uptake and impact of Thin Client technology in English schools. However, the range of refereed or official reports in the UK is still very limited. Therefore the literature review has been spread more widely to benefit from more substantial evaluation studies which have been conducted in other regions, particularly the United States and Australasia.

The literature review includes reviews of academic articles, official national reports, and school case studies (published on the Web) involving material produced by policy makers, providers, researchers and practitioners that relate to the use of Thin and Fat Client technology. The types and range of literature included are explained in more detail in Section 2.4 below. The research has covered the use of Thin Client technology by staff and students, for learning, teaching and management, both within the classroom and outside it.

2.2 Definitions

Thin Client is a generic name for a number of technologies that deliver applications via a centralised computing model.

Historically, mainframe computing environments consisted of a central 'super computer' which undertook all of the work required by a user to manipulate and store data. The user accessed this computing power via a terminal (also known as a client) with no inbuilt intelligence. Terminals could not operate if they were not attached to the network, on which the mainframe computer resided, and the transactions between the terminals and the central computer were solely character-based key stroke events and screen updates (i.e. text).

The evolution of the personal computer (PC) enabled software applications to be run locally on a system that was powerful enough to operate in a stand-alone mode. These 'Fat Clients' have software applications installed directly on to them and have local storage capability. The PC undertakes all of the processing. These stand-alone computers can be networked together to share additional services such as printers, scanners and centralised storage.

Following on from this, more powerful systems (servers) have been developed. These can host central software applications and share the processing load with the personal computer. They have been the prevalent model for most enterprise and institutional deployments and are known as 'distributed computing models'.

The proliferation of software applications (and therefore installations on each computer) has made the management of distributed models very complex, with potentially thousands of updates across the computers on the network needed whenever application updates or security fixes are required. Computers must also be very powerful to enable them to handle the volume of work it is expected to undertake.

Large networks tend to have multiple hardware configurations due to acquisition of PCs over time and from various sources. This requires the maintenance of multiple images for PC builds which adds to the complexity of managing the network.

Thin Client technology enables the software applications to be delivered from a central point. A layer of 'middleware' is deployed on a set of servers. The computer terminal sends key stroke, mouse clicks and other information to the middleware. The middleware then handles the transactions with the software application running centrally and the server performs all of the processing of the data that would have been undertaken by the desktop computer. The middleware sends screen updates (graphics) to the terminal device. The data that is manipulated stays within the central environment and only a representation is seen at the terminal. The overall speed of the system can depend on the protocols used to achieve this.

The terminal devices that can be used in conjunction with a Thin Client environment are varied and include desktop and laptop devices, as well as Personal Digital Assistants.

Bespoke terminals are dedicated thin clients with a minimal local software build. Typically these devices will have no storage capability and no peripheral Input / Output device support capabilities, although newer terminals have been developed that can support certain peripherals. These systems are low cost and have the advantages that no unauthorised data sources can be introduced via the user and that they are smaller and occupy less space than Fat Client computers.

Modern PCs can be configured to operate solely as a Thin Client or switch between Fat and Thin Client mode, and onboard interfaces can be disabled to emulate the 'locked down' status of the bespoke terminal. These can be converted back to Fat Clients (see below) if required.

Legacy PCs are older PCs that have become obsolete due to their specification being insufficient to be able to run modern Fat Client software. Because Thin Clients require less processing power and memory, these legacy PCs can often be redeployed in a Thin Client environment to extend their life.

Tubby Clients are a hybrid between the Fat Client and bespoke terminal. These machines can accommodate some local peripherals and applications and will typically also have a local storage capability. These devices can either be purpose built or built on a PC platform.

Blade PCs are computers which can sit in a bank, each one connected to a remote terminal on the network. They are maintained centrally, and the communication between the computer and the terminal uses Thin Client principles.

Fat (or Thick) Clients are computers running full operating systems with locally installed applications and storage. Fat Clients can be configured to run in dual mode allowing both Fat Client and Thin Client applications to be used.

In the project review, the school staff's knowledge of their technology was relied on to determine whether the solution in place is actually a Thin Client solution. On speaking to a sample of such schools, the researchers are confident that these judgements are sound, given the broad approach taken.

2.3 Research objectives and methodology

Specific objectives were to:

- identify and reference existing trialling and use of Thin Client technology in schools in England including a review of published research and information on projects for which there may be no published research
- identify and reference policies and initiatives related to Thin Client technology
- identify major international projects in this area that may provide additional insight into the potential use of this technology in schools
- produce a report reviewing current literature and projects, suitable for publication to an audience of policy makers and other education professionals in England.

The review provides an overview of the range of Thin Client solutions in place. It is not intended to provide detailed findings from any individual project at this stage.

As stated above, this report covers both the literature review and the project review. The methodology for each is outlined below.

Literature review

The method used for the literature review is based on that used for the two previous Becta literature reviews conducted by Professor Cox and her team at King's College London (Cox and Abbott, 2004; Cox and Webb, 2004). This involved:

- developing a framework of criteria based on existing evidence for Thin Client use in schools, to decide which published resources should be used;
- conducting a review of published evidence, both online and paper based, about the current uptake, use and related research evidence about using Thin Client (and computer networks) in schools;
- including evidence from other types of ICT uses which has implications for Thin Client uses in education.

Emphasis was placed on identifying work that is reliable and nationally relevant as well as addressing key issues. The framework for the literature review included:

- the relative financial benefits of using Thin Client technology compared with more traditional ICT technology (networked workstations);
- rationales for adopting Thin Client technology;
- the extent of integration of Thin Client technology with earlier technologies;
- policies and practices of the providers;
- advantages and disadvantages of Thin Client technology to date;
- issues identified relevant to key educational concerns.

As explained in Section 2.2 above, the literature review includes reviews of academic articles, official national reports, and school case studies (published on the Web) involving material produced by policy makers, researchers and practitioners that relate to the use of Thin and Fat Client technology, and other technologies where relevant. Some literature has also been looked at relating to the likely direction of teaching and learning in the future and the potential demand that this is most likely to make on the ICT facility and capacity needs of learners, teachers, support staff and administration staff in education institutions.

The published research has covered the use of Thin Client technology by staff and students, for learning, teaching and management, both within the classroom and outside it. The following has been covered as comprehensively as possible within the time-scales of the project:

- Academic papers reporting on evaluations of Thin Client technology;
- Relevant policy and guideline documentation from central government as a provider of national policy and related funding for teacher and support staff development;
- Asset management and ICT strategies on the websites of local government (in the form of the education departments of local authorities) as providers of local policy, direction and funding;
- Industrial literature relating to research and case studies of application in schools;
- Asset management plans, ICT strategic plans and school improvement plans for schools as users of ICT.

Direct reference to Thin Client technology has been found in much of the literature categorised above. However, where the reference is very limited much can still be extrapolated and inferred about the benefits or drawbacks of Thin Client technology from information about the likely demands that might be made on technology by possible future teaching and learning practice.

Section 3 gives the findings.

Project review

The project review element involved:

- contacting local authorities, Thin Client solution providers and ICT advisors, asking them to identify as many schools as possible implementing Thin Client solutions. (Schools were not contacted directly at this stage, to avoid placing unnecessary burdens on them.)
- agreeing a framework of questions to gather information from schools and issuing this to schools to complete. Some schools were contacted by telephone to gather the information, but the majority completed the form themselves and returned it to the researchers
- analysis of the results in SPSS and Excel.

Section 4 gives the findings.

2.4 Acknowledgements and disclaimer

The research was carried out by KPMG LLP on behalf of Becta. The KPMG team comprised Colin Tagg (Project Director), Kevin Rennie (Project Manager), Val Senior (Teaching and Learning Research), Steve Parker (Technical Research), Chetan Raisa (Technical Research) and Margaret Cox (Teaching and Learning and Technical Research). Margaret Cox is Professor of Information Technology in Education at Kings College London and led on the literature review.

3 Literature review

3.1 Introduction

A wide range of literature databases have been searched to gather evidence about previous evaluations of Thin Client and other related and relevant technologies. These include Athens and Scope, and searches through Google and Scholar-Google as well as various sites of specific organisations such as the International Federation for Information Processing (IFIP), the British Computer Society and the Institute for Electrical and Electronic Engineers (IEEE). However, compared with research into computers in schools generally which has been conducted since the late 1960s covering a wide range of IT technologies, there is relatively little published *academic* evidence of substance to date about the uptake and educational evaluation of Thin Client technology in the literature. Therefore, as explained in Sections 2.2 and 2.4 above, a significant proportion of the sources used were from official national reports, school case studies published on the Web and university reports on the rationales for using Thin Client technology. The literature results to date fall into several categories. The limited sources compared with other published research into the uses of ICT in education confirm that there will be a need for further research in this area once more institutions have taken up Thin Client technology. The types of publications include:

- national reviews of the strengths and weaknesses of Thin Client technology;
- detailed national, district/state plans based on a thorough review of the needs of the schools and colleges concerned;
- evaluations of institutions which have compared Thin Client with Fat Client technology;
- individual studies of specific uses of Thin Client technology in an institution including schools;
- academic articles reviewing specific issues associated with the uptake of Thin Client technology in education.

In the review, which follows, other relevant references are also used to support the claims about emerging issues.

3.2 Current policies and initiatives on the uptake of ICT in schools

Although the purpose of this report is to evaluate the current position of Thin Client technology in schools and colleges, it is useful to consider first the wider context of ICT in education, which also has implications for Thin Client technologies in education. Many of the government's education policies and initiatives are dependent upon schools and colleges having sufficient reliable IT resources which, as shown later in this report, can sometimes be met by the appropriate uses of Thin Client technologies. The development of ICT in schools in recent years has resulted in the UK government's e-learning strategy launched in 2003 (DfES, 2003a) and the aim that schools should develop so that they are making excellent use of ICT resources and electronic services for teaching and learning (DfES, 2003b). ICT and e-learning are to be promoted as 'an integral element of education strategies and the government programme of radical reform for the school workforce' (ibid.).

Until the last few years the government's policy for ICT in schools was that it should be used by teachers where appropriate and there was little pressure for all teachers to include it in their daily teaching. However, by 2003, this aim had been changed to an expectation that

teachers would be using ICT regularly. As stated by Charles Clarke in 2003, ‘To conclude, my vision is one where schools are confidently, successfully and routinely exploiting ICT alongside other transformational measures. By doing so they will be delivering an education that equips learners for life in the Information Age of the 21st century.’ (Ibid. p.1). Additionally, the Department for Education and Skills: Five Year Strategy for Children and Learners (DfES, 2003a) stated that ‘The central characteristic of such a new system will be personalisation, so that the system fits to the individual rather than the individual having to fit the system.’ (p.4), and that ‘It is also a vital tool for personalisation…’ (p.61). This change in focus implies that there is a more urgent need to provide regular access to ICT resources for each and every pupil whenever they need it, putting further pressure on finding cost-effective methods for providing sufficient resources.

One of the limitations to the use of ICT often reported by schools and teachers has been insufficient access to enough ICT resources. This has resulted in a succession of government programmes going back more than 30 years to try and address this particular barrier (Cox, 2005). Although substantial research in recent years has shown that another main reason for limited ICT use in schools is teachers' limited confidence and understanding of the scope of ICT for their subject teaching (Cox and Webb, 2004; Becta, 2004; Scrimshaw, 2004), it has also shown that there is still a need to provide more ICT resources in schools. Even though the number of computers in schools has significantly increased over the last 25 years to an allocation resulting in less than 4-5 students per computer (DfES, 2004a) there has always been a limitation to access to ICT resources reported by teachers. In the last few years schools have continued to report problems caused by insufficient numbers of computers (Ofsted, 2002). Associated problems include difficulties in maintaining computers, supporting the software and balancing the access between ICT lessons and ICT across the curriculum (Becta, 2004). With the increased pressure for all teachers and students to be using ICT on a regular basis, there is clearly a need to provide a way of addressing all these problems. One way of achieving this might be by using Thin Client technology, as will be shown later in this review.

3.3 Current uses of networking ICT in schools and colleges

In order to understand why some schools and not others have adopted Thin Client technology it is useful to consider the current context in which Thin Client technology is being introduced into schools. Although the majority of schools as yet do not have Thin Client networks, an important educational issue which is common to both Thin and Fat Client technology is the effects of using networks on teachers' pedagogies and classroom practices. For many years, schools in England, particularly secondary schools, have been using networks to provide ICT for whole classes and across schools (Cox, 1999). Previous research has shown that this configuration has actually influenced the ways in which teachers have used ICT in their teaching (Ofsted, 2004; Watson, 2001; Cox and Webb, 2004). According to evidence from this earlier review by Cox and Webb, the majority of teachers with networks in computer rooms have been organising the teaching and learning activities so that pupils are all working on very similar tasks, either singly or in pairs. Using such a networked arrangement, the teacher's role has frequently been that of a facilitator or guide with the main educational input being the software itself and/or a worksheet prepared by the teacher. According to previous published evidence the main use of existing networks in schools has been whole-class use or tutorial sessions with pupils working individually. Although this review has shown some similar approaches with Thin Client technology there is not enough evidence to date to indicate that it will always be used in a similar way to Fat Client networks.

A specific influence of using Fat Client networks in schools, which is shown later, is similar to that due to Thin Clients, namely the effects on teachers' and schools' choices of educational

software. Although there has been the opportunity for teachers to purchase and install a wide range of subject-based software on their networks through the e-learning credit scheme (Becta, 2005c) for their specific subject uses, the evidence to date is that the software used by the majority of teachers is still mostly generic software provided across the whole network. This has often been because the hardware provider has bundled a set of software with the network purchase which has been limited to word-processing, presentation software, email and Web searches (Preston *et al*., 2000; Cox and Webb, 2004). An interesting comparison here, as will be shown later, is that some Thin Client providers also offer 'free' educational software but this includes a range of educational subject-specific packages as well as the usual office software.

Before computer networks were widely introduced in schools (accompanied by bundled network software), the emphasis was on subject-specific software which was chosen by the teachers for particular teaching purposes (Cox, 1999; Cox and Abbott, 2004). Therefore a major influence of bringing in networks in schools has been to move teachers away from subject-based software to open-ended generic software (Cox, 2005). This trend is also clearly demonstrated through the changing software focus of papers published in academic journals over the last 30 years such as *Computers and Education*. Yet it is subject-specific software which research has shown has had the greatest impact to date on enhancing students' learning and improving standards (cf Cox and Abbott, 2004). This is not to suggest that the use of generic software does not have a powerful potential for enhancing learning, but that the majority of teachers, as yet, do not use the latter imaginatively or effectively to achieve this on a regular basis (Ofsted, 2002; Cox and Webb, 2004; Scrimshaw, 2004). This previous evidence has useful lessons for the impact which Thin Client technologies might have on teachers' pedagogical practices and on students' achievements.

Although, as explained above, until relatively recently the main use of networks in schools has been for teaching within the classroom. Research in the last few years into how students are being taught with ICT in the developed world shows an increasing use of distance learning in schools in some countries (Watson and Andersen, 2002). For example, Davis and Niederhauser (2005) conducted two case studies of distance learning in secondary education in the US. They reported that ‘During the 2002-2003 school year, over 15% of US high school students engaged in some form of Virtual Schooling defined as using technology at a distance.’ (p.249). Furthermore, with the widening use of home–school links and out of school education (Marshall and Katz, 2003) these developments have important implications for Thin Client technology in England, as is discussed more fully later on in the report. There is now also substantial evidence from case studies of schools that networks are being used for the delivery of some aspects of education, such as using virtual learning environments (VLEs) for specific courses, tutorial support and for communicating with pupils in the home (Tellerup and Helms, 2001; Crawford, 2003).

Given that Fat Client networks have significantly affected the ways in which teachers have tended to use ICT in schools, what are the arguments provided by the literature for the move to Thin Client technology on a large scale in schools? As discussed briefly at the beginning of this report, our literature research has provided a range of arguments and rationales for the adoption of Thin Client technology in schools. The next section presents some of the policy and economic arguments for Thin Client technology augmented with published evidence from projects and schools which support the educational trends in government policies discussed above.

3.4 Policy rationales for ICT and implications for Thin Client technology

There is now a significant trend in many developed countries, including the UK, for the greater personalisation of learning and for new forms of knowledge representation and dissemination (Kouzelis *et al*., 2005), which has implications for Thin Client technologies. There are rationales provided at all levels found in the literature review but those proposed firstly by policy makers are: widening ICT access and participation; rationalisation and sustainability; supporting existing and extended school infrastructures and reducing the total cost of ownership. One over-riding reason given by teachers and schools for moving to Thin Client technology has been that the lower cost of workstations and use of legacy equipment has enabled schools to provide more workstations for the same money, helping to widen ICT access and participation.

3.4.1 Widening ICT access and participation

According to Mike Gibbons (Design Council, 2005) '"The future is not what it used to be", as the saying goes. This has never been truer, which is why the government is committed to creating a very different education system; a personalised system that engages the curiosity and develops the talents of all our young people so that they achieve their potential.' (p.11). Other government policy documents state that access to ICT is important in delivering personalised learning (see for example DfES, 2003a, 2003b). The importance of access has been emphasised by the home computer scheme announced in Budget 2005 which will provide ICT to the most disadvantaged secondary school pupils. Furthermore, in the recent budget, £10 million was announced to ensure access to the internet for the same groups (DfES, 2006). Therefore an important rationale for introducing Thin Client technology in schools is to widen access to ICT for more learners. As explained below, Thin Client technology can be cheaper than Fat Client, therefore enabling schools to have more terminals for the same budget and consequently fewer students per computer. This does not necessarily guarantee greater personalisation of learning, however. This will depend upon the way the teaching and learning is organised and the specific contributions which Thin Clients can make to individual students' ways of working and their learning progression.

This position of improving education for all through the increased use of ICT has also been reiterated at the European level by Viviane Reding, European Commissioner for Education and Culture (Eurydice European Unit, 2004):

> Improving the quality of education thanks to multimedia and internet technology is one of the priorities of European co-operation. Most schools, if not all classes, should be highly computerised, all teachers should be able to use the technology to enhance their working methods and all young people should be able to broaden their horizons by using it comfortably though with the necessary critical perspective. These goals are among the priority objectives for 2010 that the education and training systems of EU countries have set themselves in the follow-up to the Lisbon strategy. (p.3).

Although there are no specific references to the types of network systems recommended for use in the EU in order to achieve wider access to ICT, that is, Thin Client or Fat Client technology, if the evidence gathered so far demonstrates that Thin Client technology can widen access to ICT more cheaply then this supports the rationale for widening its use in schools.

Widening access, as reported in the examples below, includes:

- providing ICT resources to teachers and learners living in poor remote areas previously with no access to ICT

- increasing access in schools so that teachers and pupils can use ICT in all lessons, for individual study and in other school areas for tutorials and project work

- providing access to ICT resources beyond the school, in the home, in after-school clubs etc. particularly for learners with little opportunity to use ICT outside school.

Examples of where schools involved in Thin Client projects have been influenced by the ability to increase their ICT resources and achieve ICT access to all of their pupils on a regular basis are given in the following sections.

3.4.1.1 Widening access to remote communities

Evidence of widening access through the use of Thin Client technology is provided by a number of UK and foreign studies. In a study conducted by Ho *et al*. (2005) in Mexico a mixture of different types of networks, including Thin Client technology, were used to provide access for students in remote villages. The team developed and investigated a deployment plan for the installation of computer laboratories for secondary school students in Tijuana, Mexico. Specifically, they investigated how Thin Client and long-distance wireless networking technology could be used to increase the affordability and maintainability of the computers. Their project established the co-location of school computer laboratories and public internet kiosks to minimise operating costs and create a potential for profit. This networking strategy enabled the project to provide ICT to orphanages, rural schools, high schools and special needs schools because of the lower capital costs.

3.4.1.2 Widening access within the school

One of the principal reasons for changing to Thin Client networks given by many of the schools, universities and local authorities whose reports were reviewed was to improve access to all teachers and pupils within the institution. It should be noted here that because of the few refereed published academic papers, examples taken from suppliers' school reports have also been included. These will not necessarily be completely objective because of the connection with the supplier. For example, in a school report on Thin Client technology by Stoke Damerel College (Relisys, 2006) a primary goal of the school was to ‘devise a plan to not only expand pupils’ access to IT, but also put in practice a philosophy of anytime, anyplace, anywhere ‘Martini’ learning. Feedback from pupils showed that they wanted more up-to-date systems, more of them, and higher availability.’ (p.2). According to the school, the outcome of migrating to Thin Client technology was that ‘Stoke Damerel has benefited in many ways from its application of Thin Client computing. More pupils have access to more reliable, modern IT services, but at minimal cost compared to an equivalent architecture using PCs, which would have been financially prohibitive for the school.’ (p.3)

Queensbridge School in Birmingham (also reporting on the suppliers' website), stated that before going over to Thin Client technology they had limited funds for ICT resources (emBoot Inc., 2005). One of the main reasons given by the head-teacher for choosing to adopt Thin Client technology was to increase drastically ICT access for all the school’s teachers and pupils. ‘Students did not have access to the latest technology placing them at a disadvantage compared to students at other schools.’ (p.2). The staff said that the Thin Client system ‘provides an immediate and extremely positive impact on IT at Queensbridge.

It enables the school to recycle otherwise redundant hardware and provide more students with simultaneous access to IT facilities.' (p.2)

At Camden School for Girls (Leverstock, 2006a) one of the main aims of this secondary school was to extend access from one subject department to another. 'The Thin Client terminals were originally installed in the English and Business Studies Departments. So successful were they that the school expanded provision to include a small sixth form study area and also the common room. "Sixth common rooms are not generally known as computer friendly areas," commented the Head of Sixth Form, "but the students are really pleased with the provision and there have been no problems".' (p.2) Before moving to Thin Client technology, St Albert The Great Catholic primary school in Hertfordshire (Leverstock, 2006f) had very limited and uneven access to ICT within the school. 'With just a small suite of 8 networked PCs, St Albert the Great Catholic Primary School in Hertfordshire was not able to provide ICT training to an entire class. The classes had to be split into groups, requiring extra support from teaching assistants. The resulting process was complex to manage and made consistency within year groups difficult to apply.' (p.1). The school claimed that it had been able to expand its ICT provision because it could purchase many more workstations (terminals) for a similar budget spent on the previous Fat Client networks.

According to the case study, since the installation of the Thin Client network the use of ICT has spread amongst all the teachers in Camden School for Girls and it has encouraged the head-teacher to plan for more diverse ICT resources in the future. "The current solution is all still new, but as we gain confidence we are already making tentative plans for the future. These may include additional terminals and digital cameras for each class, Interactive Whiteboards in each class and use of laptops with wireless connections, to use away from the suite for research and data-handling. In terms of our educational goals, we are aiming for all children to achieve a Level 5 in ICT, by the time they are in year 6." (p.2). Although the main advantage of adopting Thin Client technology in this school was reported to be that it enabled the teachers and pupils to have many more terminals, thereby widening access, this information was provided through the supplier's website. There may be other schools which have not found the same advantages or have opted not to purchase Thin Client networks, but literature about such schools is not published. More research is therefore needed into the reasons for the limited provision of the previous Fat Client technology in schools and in other schools not using Thin Clients to determine whether there was a significant influence from the supplier in encouraging the schools to expand their ICT provision.

For these and the other case studies which were reviewed (see also Leverstock, 2006a-f; Schoolforge, 2006) there were many other benefits resulting from the widening access within the school, some of which could be achieved by increasing Fat Client as well as Thin Client technologies. The SchoolForge voluntary organisation has over 50 case studies submitted to its website from individual schools about their ICT use, of which 13 now report using Thin Client technologies. These and the six Leverstock project schools reported greater interest and confidence amongst the teachers and pupils, motivation to develop their use of ICT even further, raising their expectations for goals in educational standards and improving the professional development of teachers. What is not yet known from these reports is whether the greater involvement and support from the suppliers was a major factor in increasing the teachers' confidence and interest, or whether it was because it was a simpler and cheaper system to use and they did not have to worry about evaluating, checking and loading educational software, for example. These additional benefits and issues are discussed more fully later in the report.

Many UK universities have also adopted Thin Client technology to run alongside other kinds of networks (such as the National Health network) and ICT resources, including Manchester,

Birmingham, Bristol, Southampton, London School of Economics, King's College London and Exeter. An important reason given for this strategy was to enable the institution to provide greater access to all its staff and students (see for example Bristol University, 2006; Manchester University, 2006). Most universities have more than one campus and a further benefit to adopting an institution-wide ICT strategy using Thin Client technology was to provide a uniform and consistent resource across all campuses and in students' halls of residence (see also Section 3.4.2 below).

3.4.1.3 Widening access beyond the school

As explained above, widening access is not just about providing access to remote communities or greater access within the institution. Another aspect is providing access in the home, where a social divide between those that have computers and those that do not is drawing increasing attention from policy makers. Parrs Wood Technology College in Manchester (2006) has extended the school network to be made available remotely to students at home. “An explicit target in the school development plan was to increase online curriculum content. However, it was clear that steps would have to be taken to enable students without home computers to access this developing curriculum. A home computer loan scheme was established following a survey to establish the extent of home access to computers and the internet. Pupils and parents were offered the use of ‘Thin Client’ terminals for home use, while the school’s PTA agreed to meet the cost of internet connection for families with financial difficulties. The terminals have been delivered to homes, set up and maintained by technical staff.” (p.2). The results of this strategy were not only to extend access for all pupils between school and home thereby providing continuity of learning and studying, but also to make ICT inclusive at all times for pupils and families who otherwise would not have had this educational opportunity.

3.4.2 Rationalisation and sustainability of ICT resources

Although widening access and participation is a commendable goal for policy makers and educators in general, previous research has shown that there are a number of specific difficulties which provide barriers to the uses of ICT even when access to ICT resources is improved (Scrimshaw, 2004). One of the difficulties which schools have had over the years of national government programmes in ICT is that they have expanded ICT resources in a piecemeal fashion which has caused specific problems regarding ongoing technical help and support for the teachers. Furthermore, it is becoming increasingly difficult to sustain the high level of provision needed to meet the ongoing ICT needs of all teachers and pupils. Leading local and national bodies have therefore tried to address this problem by providing polices and guidelines to help schools achieve a rational and sustainable approach to their ICT programmes.

3.4.2.1 Becta functional and technical specifications

Becta’s Functional and Technical Specifications (Becta, 2005a and 2005b) provide material to inform and guide schools in the practical delivery of one of Becta’s strategic aims: ‘assisting institutions to develop and maintain a coherent, sustainable and dependable ICT infrastructure by offering guidance in specifying the requirements for ICT in both functional and technical terms and offering procurement advice to support ICT requirements’ (Becta, 2005b, p.3). The functional specification provides an institution-based framework that should be achievable within the next 3–5 years which includes a detailed view of what learners, educators and administrators need to expect from the institution’s infrastructure and what functions need to be in place in order for these expectations to be met. From this literature review there are some indications that Thin Client technology can provide some of these

functions although there is still only limited evidence about how it can meet the anticipated future teaching and learning needs.

In this Functional Specification, Becta specifies a comprehensive set of requirements for an institutional infrastructure that needs to be met in order to offer learners, educators and administrators a wide range of choice and access to ICT and support. These are relevant to all institutions and technologies and four of these requirements are singled out here for elaboration. In reading on, it is important to bear in mind that the specifications need to be set in the wider context of the whole school beyond the use of ICT and that our analysis does not cover all aspects of Becta's Functional Specification.

Firstly, the ICT infrastructure needs to support individual choice by offering a range of supported applications, services and access devices to enhance the learning and educational experience for all. This recommendation supports the evidence to date about teachers and learners needing to have access to the appropriate ICT resources to meet their specific pedagogical and student learning needs (Scrimshaw, 2004). However, most of the evidence from the Thin Client literature presented in this report shows that in order to provide reliable resources across the network the range of applications is chosen to be relevant and useable to as many users as possible. This may result in only a limited range of resources being made available which might not cover the teaching and learning needs of the individual teacher, subject and/or learner. For example, one of the requirements of the national curriculum in science and ICT is to teach measurement and control which, if taught adequately, requires connecting interface boxes and input and output devices to each terminal. It was not clear from the published evidence available to date whether Thin Client networks and terminals enable this facility. However, as is shown by very recent case studies (Becta, 2006), some of the most modern terminals do have interface ports which enable interface boxes and other peripherals to be connected to them. With the expanding number of terminals reported in the cases above, when the school has moved over to Thin Client technology there could be an increased cost to cover more software licences to meet these differing needs. This of course applies to any ICT network but has not been adequately explained in the Thin Client case studies reviewed. One solution which has been taken by some schools using Thin Clients is to opt for Open Source software (Becta, 2005d; Osborne, 2006). Although this applies to any kind of institution-wide ICT provision, the implications of this and the issues raised by trying to meet this Becta specification are discussed later in the report.

In providing a range of applications, services and access devices, as Becta notes in its technical specification (Becta, 2005b, p.20), 'it is likely that an institution running a Thin Client network will wish to have Fat Client laptops for use off line, which then run a 'terminal emulation' program to act as a Thin Client whilst wired to the network.' This is because any laptop configured to work solely as a Thin Client will be unable to function when it is removed from the institution's network.

The second specification stipulated by Becta (ibid.) is that ICT should support flexible working in schools, as identified in Section 3.4.1 above. This requires a flexible ICT provision which will support learners, educators and administrators, so that they have a range of ways and locations in which they can undertake their daily tasks. In the case of Thin Client technology, as explained above, because schools were able to purchase more terminals this provides greater flexibility in where and when teachers and learners can work. However, as is explained later, the actual different types of ICT resources (software, hardware and peripherals) available over a Thin Client network can, in some circumstances, be fewer than on a Fat Client system, so this can reduce the flexibility in terms of being able to choose from a wide range of resources for teaching a particular subject. With the flexible working

comes the requirement for the network to remain operating faultlessly at all times. Some of the schools reviewed here have reported previously having *several* Fat Client networks in a school, for example, one for the administration, another for the teaching staff and several for different ICT teaching laboratories. If one failed there would still be access to ICT through the others. An issue which emerges from replacing several networks with a *single* Thin Client network is that the benefits of providing flexible working across the school may be reduced by the problems of sustaining an operating network at all times. However, the same problem applies to any kind of single ICT network and, as found in many of the school reviews, there should be arrangements to provide back-up if the main network goes down.

The third Becta specification is that ICT should be used to manage data and improve efficiency. The user needs to have confidence in the ICT infrastructure to deliver a fast and reliable service, regardless of the task in hand (the Case Study report examines this in more detail and found that the lack of support for the school's management information software whilst running on a Thin Client network was an issue for schools). An advantage of Thin Client technology, as is shown later in the report, is that it makes it easier to ensure a uniform resource which teachers and students can use across the school. Although most schools using Fat Client technology do standardise their networks as much as possible (Barking and Dagenham LA, 2005a), limited annual budgets often result in new networks being used alongside older networks so that not all user stations have the same configuration (Bedfordshire LA, 2006a-c).

Providing a consistent and reliable system has been shown to improve teacher confidence. This is because during teaching and learning sessions they are less likely to have technical problems and they find the technology easier to use because wherever the ICT network is being used in the school, the interface and software are the same.

The final Becta (ibid.) specification is using ICT to secure data and protect the user: all institutions need to ensure that any data is held securely and that users are offered a range of protection from inappropriate ICT resources. Because Thin Client technology requires users to store all applications and other data on the main server this provides better data security and reduces the chances of viruses entering the system and affecting the school's work. However, this improved data security through using Thin Client technology reduces or prevents the flexible uses by teachers and pupils that are available on Fat Client networks where pupils can save school work on their own disks or bring in their homework on disks and improve upon project work in lessons, having loaded it onto their local network. Instead, workarounds such as emailing the work in may need to be adopted to get the information onto the Thin Client network. (Note that Becta has advised (Becta, 2005a and 2005b) that information should be stored on central servers and not local disk drives, whether it is a Thin Client network or a Fat Client network, so well managed Fat Client networks can also offer data and virus security.) In addition to the benefits discussed in this section there are many other ICT-related practices discussed later in the report which could conflict with installing Thin Client networks across the school.

Becta's technical specification (Becta, 2005b) also sets out some clear advice on the advantages and disadvantages of Thin Client technology and is worth quoting in full:

'Thin Client' networks, where most of the processing of data occurs on the server, have a number of advantages over the more common 'Fat Client', with cheaper terminals, central application control, and enhanced security. However, there are also clear disadvantages to such an implementation: Thin Clients are usually less able to deal with complex video and audio demands; and specialised Thin Client terminals lack the flexibility offered by Fat Client machines.

The servers in a typical Thin Client network require sufficient processing power and memory. With all the clients on the network demanding that their processing be done on the server, the specifications of the servers (and thus their cost) may need to be higher than the servers in a Fat Client environment. However, the extra cost of these servers over a Fat Client solution can be offset by relatively cheaper client machines. The reliance upon these servers is not seen as a major disadvantage, as it is usual that a Fat Client implementation will be equally reliant upon the network server. The loss of a server with certain Fat Client operating systems can render those Fat Clients useless.

Thin Client solutions do often require more servers than Fat Client architectures. As all the processing for a Thin Client implementation is done on the servers, there are limits to the number of concurrent users that a Thin Client server can support. It is vital that institutions that implement a Thin Client solution consider the number of users that may use the system concurrently and ensure that their servers are sufficient to support this.

A properly implemented Thin Client will use little more bandwidth than a properly implemented Fat Client architecture, however there is an increase in the number of network packets generated by a Thin Client solution. As these packets are small and frequent, it is vital that the network is built around hardware that can process these large numbers of packets in a timely and accurate manner. Wireless networking makes available lower bandwidth, and is often subject to greater packet loss than wired networking, and therefore performance may suffer if a Thin Client solution is implemented over a WLAN.

… it is not advisable to configure laptops as Thin Clients if they are required for use off the network. Any laptop configured in such a manner is likely to be unable to function when removed from the institution's network, as it will no longer have a connection to the server from which its applications run. Thus it is likely that an institution running a Thin Client network will wish to have Fat Client laptops for use offline, which then run a 'terminal emulation' program to act as a Thin Client whilst wired to the network. Whilst this is entirely possible, it can lead to user confusion as the user may require a different login procedure depending on whether the device is connected to the network or not, and therefore care must be taken to ensure that users understand the logon procedures required.

Becta concludes 'it is strongly recommended that an institution study very closely their functional requirements before deciding upon a Thin Client network as their main wired network; and most institutions will wish to seek assistance from their networking partners before committing to Thin Client networking.' (ibid, p. 20)

3.4.3 Examples of rationalisation and standardisation strategies in schools

As a result of a district-wide survey (Sun Associates, 2001) a three-year strategic plan for educational technology was developed by Yorktown Central School District in the United States which provides useful examples that are relevant to the UK. One of the main rationales for moving to Thin Client technology was to achieve more uniform provision of hardware and software across the school district rather than any possible cost savings. However, the migration to Thin Client technology was planned to include important educational initiatives already identified as a consequence of this and other access and standardisation rationales. These included three main goals:

Goal 1 – We will develop partnerships between our school and the community, as well as between our school and neighboring schools, to obtain support, expertise and resources. (ibid. p.40)

Goal 2 - We will provide opportunities for community members to use technology resources at school, at home, and at other locations throughout the community. (ibid. p.42)

Goal 3 - We will maximize our use of our current technology resources and continue to explore new technologies to improve communication with community members. (ibid. p.43)

The district would also continue to gather data from staff and community on technology needs and issues; continue the development of district benchmarks and standards for the use of technology in teaching and learning; review and revise the K-12 curriculum maps and conduct ongoing assessment of staff professional development needs. This report indicates the importance of having a holistic approach to migration which takes account of both curriculum needs and staff development needs. These are elaborated further in Section 3.5.6 below.

Standardisation was also a priority for Dundee City Council, which decided to implement a Thin Client solution for a range of its council office workers, starting with a pilot in their Education Department (Computer Weekly, 2002). They cited the main reason for doing so as: ‘the need to look at the increasing unsustainability of supporting disparate PCs, each with a slightly different configuration’ (p.3). The solution was not implemented wholesale. Some technical staff, including architects, who needed high-performance graphics software, were allowed to retain their personal computers. However, with the 650 terminals that were installed, annual cost savings of 35 per cent were reported (p.2).

A number of other LAs whose websites were examined had clear policies for developing and supporting the use of ICT in schools but not for standardising on Thin Client networks. These included:

- Barking and Dagenham (2006a,b) which is one of three LAs selected by the DfES to be part of the £20m ICT Test Bed Project to demonstrate the impact that high levels of investment in ICT can have in education. Thin Client technology is not being considered at the present time although the LA clearly has a wide understanding of the contributions which ICT can make to its schools' education programme.

- Bedfordshire LA, which has a number of clear statements that relate clearly to central government's priorities (Bedfordshire, 2006a-c), improving practice regarding teaching and learning and improving communications, both being served by improvements in ICT networking but no plans to standardise on Thin Client networks in its schools.

- Derby City Council's asset management plans (see Derby, 2003a,b; 2004a-c) included a number of schools that already deployed Thin Client technology but there were no plans to standardise on this across all its schools.

- Leeds LA's Education 'ICT and Information Management Strategy – 2004-2007' (April 2004) outlines specifically (pp.21,23–30) the part ICT is intended to play in the delivery of 'more individualised learning for young people which addresses their achievement histories, intellectual characteristics and learning styles' (p.21). Again, however, it does not enter into any discussion, or make any recommendations about the types of network system which their schools might use to deliver these aims.

- West Sussex County Council (2006) has a number of very clear statements about the role of ICT in improving both the quality and the flexibility of teaching and learning. It does not, however, make any recommendation or outline the benefits and drawbacks of the different network systems that schools might use to deliver their aims, even in terms of general themes such as Thin and Fat Client.

Although there are no direct references to Thin or Fat Client technology in most of these local authority documents, it is clear that with the exponential growth in the use of ICT facility as a support to teaching and learning and administration of schools, and the associated expenditure of vast sums of money to try and achieve this, clear information and guidance relating to Thin and Fat client technology would be of enormous benefit to the LAs and through them, to their schools.

As might be expected, the standardisation of ICT resources is also a strong argument put forward by ICT suppliers for installing Thin Client systems (e.g. see Integrex, 2006, Precedence Technologies, 2006). They outline the main benefits of Thin Clients, which have also been supported by some of the school evidence in the case studies (see Section 4 below). These include solving many compatibility issues; dispensing with the need for individual computers to be upgraded, reconfigured and replaced; being cheaper than Fat Client technology and requiring less 'manpower' to support. One useful strategy, which these suppliers have adopted, has been enabling schools to utilise 'old' PCs which would otherwise have been past their obsolescence deadline. This is because when used in Thin Client mode the slow processing speeds on these 'old' computers does not matter. (It is worth noting that Open Source software can run on older, lower specification computers). This provides an alternative method for schools to make use of legacy equipment. However, using them as Thin Client terminals, where processing power is even less important, may enable legacy equipment to be used for longer. The lifetime of computers can also be extended using other operating systems such as Linux, which has less demanding hardware requirements than many proprietary operating systems.

The school reports provided by suppliers are likely to be subjective. However, an important outcome from these, which is supported by the more objective references and the project review, is that to obtain standardisation using a Thin Client solution does not require schools to have to jettison their 'old' PCs, which would add to the cost of new installations. Most of the suppliers' and schools' strategies reviewed have involved augmenting their existing ICT resources rather than replacing them when installing a larger Thin Client network. In spite of this they have managed to achieve standardisation and reliability with the existing PCs still in use. Therefore migrating to Thin Client technology can actually put new life into a school's old technology which previously most schools would not have been able to achieve.

An issue which is emerging here is whether or not state secondary schools may benefit from some standardisation within the school or at an LA level. The evidence to date shows that a

standard ICT network provision is more easily achievable with Thin Client than with other types of networks, as shown above, and it enables the schools to have a common platform and user interface (though that is not to say that a well-managed Fat Client network cannot offer the same benefits). In some schools this gave teachers more confidence to use ICT. Meanwhile at the local level it enables LAs to provide more support, although teachers and schools may experience a loss of the richness and diversity of ICT. However, local authority policies of standardising the platform across their schools are not confined to Thin Client networks. For example, as explained above, in Barking and Dagenham there is very strong guidance and support for ICT in schools (Barking and Dagenham, 2000a,b) and all state schools in the authority follow the same ICT strategy.

3.4.4 School infrastructures and the uptake of Thin Clients

The specifications discussed above (Becta, 2005a and b) not only apply to existing school structures but also to new school structures which are currently being considered to meet the government's policy of upgrading and rebuilding schools (DfES and PfS, 2004). The 'Technical Specification - Institutional Infrastructure' report produced by Becta in 2005 (Becta, 2005a) discussed above maintains that a clear standards-based approach will help to ensure that infrastructures designed today are able to offer an ICT resource to the institution that is useful both today and in future years. As has been shown above, Thin Client technology can also make use of older machines that otherwise might have been made obsolete.

The national Key Performance Indicators for the Building Schools for the Future (BSF) project (DfES and PfS, 2004) specifically relate to readiness of the ICT infrastructure – networks, wiring, and wireless facility for terminals, laptops, interactive whiteboards. BSF has developed a template specification for the provision of a managed infrastructure service in a BSF school. They propose that the amount of ICT infrastructure for future developments should also try to be anticipated and, with the start-up needs, be outlined in the ICT specification in the local authority and/or school development plans. This forward planning for ICT provisions should be sufficiently well resolved and determined in order to avoid subsequent disruption in later years, that is, there should be no need to extend the infrastructure.

The current evidence about Thin Client technology presented in this report shows that it could help schools achieve a common platform and access across the whole institution. However, alongside these recommendations there needs to be equal consideration for improving teachers' pedagogical practices and pupils' learning, and raising educational standards, as stated in the Becta and BSF specifications (see above) and which are discussed more fully in Section 3.5 below.

An earlier study conducted by the OECD at Crocodile Valley Secondary School in British Columbia (Wilson *et al*., 2001) evaluated the effects of Thin Client technology on the integration of ICT into the school. From its early example the researchers showed how the school made use of existing PCs for innovative uses of ICT but a nearby school which was more advanced and only recently built had taken up Thin Client technology. The strategy for this Canadian district was therefore (in 2001) to be adopting newer technologies alongside new school builds. In other words, they installed Thin Clients when there was a need for major structural and other changes in the school. A possible reason for this was that the schools' educational resources could be more radically reviewed when major changes were taking place generally in the buildings themselves. 'Today, there are comparable ICT resources at all of the district secondary schools; some have newer technologies in place, but these most often serve as a testing ground before being adopted district-wide' (ibid.

p.20). This report shows a completely different strategy to adopting Thin Client technology in schools to that discussed earlier for Yorktown district schools. The latter decided to standardise the technology using Thin Clients across all schools in the district in a comprehensive programme whereas the former decided to install it alongside major building developments and thereby try it out in some schools first before expanding it to all the other schools. Apart from the conclusion that the Thin Client option would be cheaper and could therefore be more extensively available across the school, the conclusions of the OECD study were that it was most easily adopted when there were major changes being made to the schools themselves.

3.4.5 Reducing the total cost of ownership

One of the overriding rationales found in this review for adopting Thin Client technology has been to overcome the escalating costs of maintaining an up-to-date and reliable ICT resource in schools. As has been discussed earlier, schools are still finding it financially difficult to meet the many conflicting ICT requirements (see for example Australian Capital Territory, 2003; Ofsted, 2004; Becta, 2004) even though as explained earlier many schools are not using all the resources available to them, such as e-learning credits (Becta, 2005c; Cox, 2004). The majority of the studies reviewed reported reducing ICT costs to be their primary consideration. Schools have to fund improving their ICT provision along with many other resources and infrastructure needs. The school reports reviewed show that this priority sometimes overrides any pedagogical or subject teaching priority (Schoolforge, 2006). For example, for the School Forge case study schools (ibid.) the numerous benefits of installing Thin Client systems given include: continued utilisation of what would otherwise be redundant computers (hardware); installation of software onto servers only; and stability and reliability of the systems.

A review of the total cost of ownership of ICT resources in schools by Scrimshaw (2004) provides a useful definition to base our discussion on here. ‘Put at its most general, total cost of ownership is the sum of all the costs associated with a given aspect of an organisation's work’ (p.6). In the case of this report, the aspect is ICT but with a focus on Thin Client technology. According to Scrimshaw, the business approach to TCO can exclude important costs such as teachers' continuing professional development, assuming that teachers and other staff will learn on the job. The TCO for ICT in schools includes the costs of the hardware, software, senior management time, staff training, network technicians, maintenance contracts, management costs, licensing and security costs. Although it is outside the scope of this review to address any of these in great detail and the results did not provide evidence of most of them individually, some useful findings regarding some of the costs have been identified.

The main cost reductions associated with Thin Client technology reported in this review were for hardware, software, maintenance, downtime and technical support. An important point to note is that the reduction in costs reported by the 25 schools whose cases were published on different websites was quite often due to secondary effects (softer costs). For example, having the network running for 24/7 made better use of the system although this did not in principal require a Thin Client network as is explained later below.

3.4.5.1 Reducing hardware costs

Although this is reported by the providers and therefore is not an independent finding, a common finding across the Cutter project schools (see Osborne, 2006, The Cutter Project, 2005a-d) was that costs could be reduced both in terms of installation and long-term running costs when moving to Thin Client systems. This was also an important rationale reported by other local authorities in their decision to move to Thin Client technology (see, for example,

Derby City Council, 2004c, and Sun, 2006). More specifically, schools reported benefits such as being able to re-use existing hardware without any upgrades; PC booting no longer used the local hard drives so is quicker, and the life of the workstations is prolonged by several years. However, these cost savings in several of the schools assume using existing PC work-stations and not necessarily purchasing as many new client stations with the new network.

The study conducted in Mexico discussed earlier (Ho *et al*., 2005) identified a number of cost benefits to using Thin Client technology. 'The capital costs are lower because 1) the Thin Client is not required to have a hard drive, 2) it can run well with less memory, and 3) it requires a much less powerful processor. Furthermore, operating costs are lower because 1) the disk drive is the computer component most likely to fail, 2) the absence of a disk drive means that the Thin Client cannot become infected with viruses or spyware, 3) a single upgrade to the server will automatically result in upgrading the clients, 4) there are not software compatibility problems between different clients, as they are all effectively graphical terminals for the same machine, and 5) the presence of the terminal server enables easy centralized management.' (Ibid. p.8). There are many other costs savings related to these within centralised management which were not reported in detail, such as being easier to install software, helping provide greater security and so on.

The majority of the sites being studied in this Mexican project had PCs donated from industry and charities and did not all have the initial funds to be able to move over to Thin Client machines. In this project, the main barriers to configuring the PCs as Thin Client terminals was that there were insufficient funds to upgrade all the ICT resources provided. The project had a limited budget and its overriding priority was to provide computers to the very poor schools and aim to upgrade all the donated PCs to Thin Client terminals when more funds were available.

A secondary cost benefit identified by some schools in this review was that the need to replace older machines for Thin Client networks was much reduced. This therefore saved on having to find back-up terminals. For example, one of the schools using a Thin Client system (Surftec Ltd, 2006a–f) had its Thin Client technology initially installed in 1998. Since then it has added to the system, but has not had to take out of action any of its original machines, which are all still able to work from the new servers. This same school shares its servers across sites with another school.

Relysis' website (2006) carries a case study featuring Stoke Damerel Community College which was able to transform an ageing and expensive PC architecture by deploying Thin Client technology. In the college's own report on the website, it maintains that this change has not only raised its teaching standards and transformed its learning culture but has also enabled it to make significant savings on IT capital and operating costs. The Business Manager maintains that the college has saved hundreds of man hours on systems administration and dramatically cut its total cost of ownership of IT systems by thousands of pounds. The main benefits reported by the school staff were that the Thin Client network was cost-effective to buy and run. This meant that the school could afford to buy more 'clients' than would have been the case with Fat Client PCs. New clients can also be deployed more quickly.

3.4.5.2 Reducing the costs of maintaining and operating the hardware

As well as a cost saving in purchasing the hardware, several studies (see, for example, the Schoolforge case studies, 2006) reported that they had chosen Thin Client technology because otherwise the costs of upgrading both hardware and software were well outside the

parameters of the schools' budgets. The decision was also often influenced by recommendations from teacher colleagues in other schools that had already installed Thin Client systems. Significant reductions in both installation costs and TCO were reported.

The Thin Client system used by Stoke Damerel Community (see above) was also reported to have greater reliability, robustness and security and to be more economical space-wise. They also claimed that there were energy savings (terminals use less energy than PCs) and the quiet running of the terminals meant a better teaching and learning environment.

3.4.5.3 Reducing the software costs

Most of the case studies reviewed here reported reduced expenditure on software after moving to using Thin Client networks. However, the strategies used to purchase or acquire educational software were not confined to Thin Client technology. Several of the schools reported moving to Open Source software (OSS), which is mainly free and therefore the teachers and schools believed that there was a significant saving in reduced software licensing fees. Although OSS is not confined to being used on Thin Client networks and could be regarded as a separate issue, the teacher reports repeatedly referred to the Open Source software being provided by the Thin Client suppliers as an additional bonus. This has a number of educational implications relating to the teachers' and schools' possibly limited understanding and knowledge about the range of educational software available through e-learning credits for example. There was relatively little evidence of the impact of the Open Source software on ICT subject-based resources and thereby on the learning of pupils.

In some situations in the Mexican project, internet access was prohibitively expensive and the 'Delay Tolerant Networking (DTN) architecture sought to address this issue by allowing the use of intermediate mobile entities (a.k.a. a guy on a motorcycle with a USB key in his back pocket!) to transport data from a well-connected location to computers in locations without direct connections to the internet' (ibid. p.14). The results of this study showed that although Thin Client technology could be cheaper, as explained above, and therefore be more accessible to poor communities, the wealth of software which was being used on the PCs could not be supported by the Linux environment being used without significant additional costs. If a Thin Client solution is to run using similar Linux software, availability of software might be an issue although there are ways of running proprietary educational software with a Linux-based system that could overcome some of the limitations reported above. Furthermore, as already shown, Thin Client solutions are not limited to Linux software.

3.4.5.4 Reducing downtime and obsolescence

Another cost saving reported in some studies was by reducing the downtime of the network. One school reporting on the Schoolforge website (2006) had had Thin Client technology installed in 1998 and had never had to take any machine out of service since then. The reliability, versatility and cost effectiveness of the system had enabled the school to extend the provision to more and more learners each year. In 2003 major new installations and modifications took place over a period of only three days. The system now enables staff and learners to access the network from home. The school feels that it is the relatively low costs of the Thin Client technology that have enabled them to maintain access to current software and provide sufficient capacity to meet the demands of the school curriculum and learners' personalised learning needs.

Other benefits reported earlier which have implications for reducing the downtime and obsolescence include the fact that it is simpler to maintain a Thin Client network because the main task is running and maintaining the central server(s). As a result there is less cost lost

through one or more terminals being 'down' and the time that was spent by individual teachers and other members of staff in getting them repaired or replaced. As explained above, the life-time of older PCs and Thin Clients is extended because the operation is less dependent upon the local memory and functionality of individual terminals. This reduces the costs incurred by replacing obsolescent terminals.

3.4.5.5 Technician support

Although the costs of providing technical support for any ICT system can be significant, several schools reported that the Thin Client systems greatly reduced the workload of support technicians, so schools could employ fewer, or share this resource amongst schools. There are many other aspects to this cost reduction but little evidence was reported in the literature available for this study.

As explained at the beginning of the report there are relatively few academic research studies as yet into all the possible areas of Thin Client use in schools or of the Total Cost of Ownership of ICT in schools.

Four important limitations emerging from the evidence presented in this TCO section are:

- The evidence for the TCO was only available from 25 schools which reported cases on the Web and a further 10 schools in academic studies. None of these had conducted extensive research into the total cost of ownership so the findings are mostly qualitative, relying on the accuracy of the school reports and some more detailed findings in the academic papers.

- The total cost of ownership calculations in these schools is complex and can mask savings made such as by using old existing technology, limiting the educational software and thereby reducing technician costs.

- Some of the savings reported were not specific to Thin Client technology but only came into effect when the school switched from Fat to Thin Clients. Therefore the actual savings reported, such as using Open Source Software, were not directly as a result of using Thin Client networks but more as a result of the influence of the supplier. There is clearly a need for further research into this specific factor, which is elaborated in the conclusions.

- According to the researchers' evidence, the calculation of the Total Cost of Ownership in some models does not clearly include the cost of ongoing teachers' professional development. This can outweigh all the other costs (see for example Preston *et a*l., 1999, and Cox and Webb, 2004).

Although the main cost benefits reported in this section are based on a limited range of 25 school cases, a few LEAs and academic studies, those cost reductions discussed above (hardware, software, reducing downtime and technical support), were repeated by many of the different schools and studies, giving some credence to the cost benefits discussed. In addition to the cost savings there is also evidence to support specific benefits to teaching and learning which are discussed in the next section.

3.5 Teaching and learning implications

Although, as discussed above, the main benefits reported in the literature published to date for using Thin Client technology in schools are to widen ICT access and participation, the rationalisation and sustainability of ICT, supporting existing and extended school

infrastructures, easier management and support and reducing the Total Cost of Ownership, these have implications for teaching and learning using ICT. Specific implications identified are: the effects on types and range of educational and other software, extending the uses of ICT in schools, the impact on the curriculum, learners' contribution and access; beyond the classroom; autonomy of the learner; and the continuing professional development of the teacher.

3.5.1 The effects on types and range of educational software

A number of strategies have been adopted to provide a range of educational software on Thin Client networks. These include providing 'free' educational software through Open Source software (Osborne, 2006), providing generic software stored on the main server (Schoolforge, 2006), and providing software purchased through the Curriculum Online website (see below). However, there is no mention amongst these reports of the types of software needed to teach aspects of the curriculum such as measurement and control which requires the use of Interface boxes connected to sensors and switches, as discussed earlier. The strategies reported to date imply the use of software on the network that does not include any educational peripherals. These strategies partly depend upon the type of Thin Client network which has been set up in the school (and home). In a similar way to the evolution of the hardware in schools, where many currently have a mix of older and newer technology, the same has happened with educational software. The most significant influences the researchers identified on the types and range of software available in a Thin Client school (as in schools with other types of networks), are: the technological history of the school; the choice of the Thin Client network; the existing ICT pedagogical knowledge of the teachers and headteacher; the local authority; the budget available; and the network supplier.

3.5.1.1 The technological history of the school

In spite of the generous allocation of e-learning credits in the last few years which can be used to purchase educational software, the majority of schools do not use their full quota (Becta, 2005c; Cox, 2004). Research evidence from the last 30 years has shown that the choice and range of software can be strongly affected by the hardware resources acquired by the school. At the beginning of the 1980s the majority of schools and teachers who had computers had stand-alone BBC and Research Machine computers with disks of subject-based educational software, with the occasional early educational word-processor or database package (Cox, 1983). The emphasis was on the teacher selecting and using particular software packages to meet a particular subject need. With the advent of the early networks of computers came the bundled generic software in the mid 1980s which was specifically designed for use in offices and industry. Teachers believed and expected that they should focus on using this type of software in their teaching. Very little money was set aside to purchase any other subject specific or educational software, resulting in a shift from using purpose-designed educational materials to software provided by the suppliers. In other words, they were led by the choices made by the supplier. From the evidence available to date in this review this is now also the case for most schools adopting Thin Client networks.

As a consequence of the advent of networking in schools in the early 1980s there was an unintended detrimental restriction on teachers to try and use software initially designed for non-educational purposes. According to many research studies this was one of the reasons why ICT as a subject, introduced some years later, and ICT across the curriculum fell behind other subjects and curriculum developments in schools (Ofsted, 1994; Beauchamp, 2005; Cox, 2005). A specific effort was made to overcome this with the launch of the latest version of the national curriculum for ICT in which specific generic software applications are not mentioned in the Programmes of Study (see National Curriculum, 2006). With the growth in

demand for computers in schools and pressure on suppliers to provide educational software, there has been more educational software development over the years to fill this gap. However, Ofsted's report (2004) still shows that the predominant software use in schools is that provided for general purpose use but now includes presentation and internet software. The limited evidence on Thin Client software use suggests that schools and teachers are still being influenced by the suppliers and what can be purchased and supplied centrally. The researchers found no mention of any specific subject-based software being purchased to be installed on the Thin Client networks apart from the Open Source software and some suppliers providing educational software ordered through the e-learning credits scheme.

The case studies reviewed earlier show that when schools have migrated to Thin Client networks they have been able to have some of the less media rich educational software previously used on PCs, installed onto the Thin Client server. For schools that are not able to use some titles, they may be able to work around this by enabling legacy PCs to operate as Fat or Tubby clients. These machines can have a range of software loaded onto them which may not be available on the network.

Some Thin Client schools have been able to make their own choices of educational software and other resources through the suppliers who have registered as third-party suppliers of Curriculum Online resources. This strategy should provide incentives for teachers and schools to review the very large range of educational materials available for purchase with e-learning credits. Other school cases, however, have clearly previously focused on using generic software and secondary schools being much larger on average than primary schools, have to pay more for site licences where they operate Thin Client systems. In the case of the four Cutter Project Schools (The Cutter Project, 2005a-d) the supplier lists the software provided for their network which includes generic software and also a large number of free Open Source educational programs (see for example The KDE Edutainment project, 2006). In reviewing their software list briefly, the majority are of the tutorial and drill and practice types which have some value for learning but do not provide the same educational challenges as simulations and modelling software for instance (Cox and Abbott, 2004). Because of the limited number of substantial published school cases or research projects to date, it is not possible to draw any clear conclusions about the likely future trends in software use on Thin Client networks. However, from past history it is clear that educational software will become more versatile and powerful in terms of options, graphics and icons and images which might make it more difficult to run on very minimal Thin Client terminals. Furthermore, there is still a requirement to teach measurement and control in the national curriculum, connecting sensors and switches to computers as mentioned earlier. This can be difficult to achieve with some Thin Clients. This is an area which needs substantial further research since it has not been taught well in the majority of schools in the ICT curriculum (Ofsted, 2004) on Fat Client networks, let alone on Thin Client ones.

Although there is evidence of Thin Client terminals restricting the use of extensive graphics software in English schools, there is also computer science research in the US which shows that there may be ways of overcoming this restriction in some circumstances and for some applications. In a study conducted by Jones (2004), he examined the viability of providing a rich graphical package (referred to in the study as a 3D On-line Distributed Learning Environment) to students at North Texas University. He found that the current generation of such learning environments could be delivered using Thin Client technologies even across networks which had relatively slow internet connections such as 33Kbps. He claimed that one way of providing images for teaching was to create a 3D rendered environment which is highly bandwidth efficient. This means that it can easily support those without access to faster internet connection, at 256 Kbps. 'At the same time, this same approach can grow to accommodate higher-bandwidth and more multi-media objects as access to faster internet

occurs over time. Users can interact (chat, audio, e-mail, conference, overheads, etc.) with other students and the instructor inside environments in real-time using a 33 Kbps modem connection to the internet. Once objects and textures are transmitted and cached on the local computer, the bandwidth can be tasked for higher priority information like audio and text' (ibid. p.4). A fast performance over Thin Client internet connection is ensured by small file sizes and delivery of 'just in time' information. However, the author does not discuss how efficiently this would work when there are many users as in a school, for example, as is discussed below.

There are similar developments in computer science research in the UK but these have not yet reached the schools' market. A useful earlier review of the history of networks (Jamilah *et al*., 1996) describes the development of 3D software and similar computer architectures to the one above which have been developed for use in Computer Science. The implications from these two studies is that the versatility of software, including 3D images, will continue to expand but may still be accessible over Thin Client networks as the hardware and software (system and application) become more powerful.

3.5.1.2 The choice of Thin Client network

The case studies reviewed in Section 3.4 give a number of different configurations of Thin Client networks which have been adopted by schools, local authorities and universities. The choice is, as explained above, partly influenced by the history of the institution and by financial considerations. An important consideration for many of the schools was to be able to continue to use their older PC terminals on their 'new' Thin Client network. This appeared to be possible with all the cases reviewed.

Several schools referred to earlier had chosen the Thin Client provider because of recommendations from colleagues, but an important consideration was that they could still access software which they had been using previously. The Thin Client providers also offered free educational software such as Open Source software which was an incentive to schools because of the financial savings involved (see for example Leverstock, 2006a-e; Schoolforge, 2006). There was a significant range of emphasis in the school reports on the priority for obtaining the more appropriate software. This ranged from specific reference to the importance of having a Thin Client network which would enable them to keep using their existing software as well as new software, through to those schools which were happy to move to new software and chose the Thin Client mainly for its cost-effectiveness in providing more terminals and its sustainability.

It is important to note that in choosing a Thin Client network, there are many technical issues relevant which were not reported by the schools or academic studies, such as some software needing local access to directories, the use of multimedia, video conferencing and as mentioned earlier, measurement and control.

3.5.1.3 The existing ICT pedagogical knowledge of the teachers and headteacher

Most of the literature reviewed here has little substantial evidence about the pedagogical knowledge of the head-teacher or the teachers in the school regarding their reported usage of Thin Client networks. There are statements expressing an important criterion for choosing a Thin Client network to be one which would provide access to a range of appropriate educational software, but in many cases the emphasis was on connectivity or reducing the cost of hardware.

Previous research into teachers' pedagogical knowledge (Webb and Cox, 2004) has shown that there is still very patchy understanding amongst headteachers and classroom teachers about the scope and potential of educational software, whether it is generic open-ended software or more subject specific software. An important area for further research is to establish how teachers' and head-teachers' pedagogical knowledge influences their choices of educational software and ICT resources in general. The limited evidence here implies that even if the teachers and head-teachers do have sound pedagogical content knowledge about the use of ICT in education, it was not evident in their reasoning for choosing Thin Client networks. This implies that the schools may not be aware of any limitations to educational opportunities caused by migrating to Thin Client networks.

3.5.1.4 The local authority

The examples discussed in detail above in Section 3.4 have already shown that local authorities can be a significant influence on the choices which schools make about which hardware and software to purchase. Amongst those reviewed in this report there are very well thought out programmes for the growth of ICT in schools, including the scope and range of educational software which their schools have been recommended to use (see for example Barking and Dagenham, 2005a; Bedfordshire Local Authority, 2006b; Derby City Council, 2004b). During the 1980s and early 1990s local authorities had a very large influence on most aspects of schooling in their authority including what software to use. However, when the local management of schools policy was introduced by the government in 1987, this removed much of the local authority influence on schools. Therefore the extent of current local authority influence on the acquisition of educational software on Thin Client technology in schools is very varied across the country. Several of the school case studies reviewed here do not mention the influence of the local authority on their choices of ICT resources but do mention the supplier, who appears to have a significant influence on many schools. However, there are limitations to the value of this result since firstly, some of the cases were provided on the suppliers' websites so may be less than wholly objective. Secondly, some schools were located in local authorities which had devolved most responsibility and funding to the schools so had relatively little contact on a regular basis. What could not be measured in this review was who influences the schools which have chosen not to adopt Thin Client technologies as yet.

3.5.1.5 The network supplier

The evidence from this literature review (see the caveat earlier about some of this being published on the suppliers' websites) shows how closely some of the schools' senior management teams work with the Thin Client suppliers. This includes deciding what types of machines to purchase (including keeping the older ones), how many networks to have, where the servers and terminals are to be located (including locating some terminals in the home) and what kinds of software they will be able to use on them. What is not evident from the literature and evidence to date is how schools choose a particular supplier for their Thin Client network. It is clear that the supplier has a significant influence on what software schools might obtain by offering free Open Source software (see for example Surftex Ltd, 2006f) and by providing a set of bundled software on the network. What has been shown by other researchers, however (Banbury and Brown, 2000) is that if an institution with a large number of users, such as a large secondary school, wishes to have access to a range of educational software through licensing arrangements then the cost of this can mount up. Clearly, while the e-learning credits are available, such costs can be ameliorated by these, but this is still an important consideration when calculating the Total Costs of Ownership.

A further point about the suppliers' influence on the purchase and acquisition of educational software is that they are unlikely to have the extensive subject knowledge to be able to

provide appropriate advice. More work therefore needs to be done to help schools understand what kinds of educational resources they should be including on their Thin Client network and whether or not they will be able to be run satisfactorily.

3.5.2 Extending the use of ICT in schools

A relevant and substantial part of several of the studies which reported on their reasons for moving to Thin Client technology was a survey of teachers and other educators of what they currently used in their schools and colleges and what they perceived their needs to be. For example, as discussed in Section 3.2 above, Yorktown Central School District in America conducted a technology audit of its teachers, administrators and community members between 2001 and 2002 to establish the uses of ICT in their schools and what would help them use ICT more effectively (Sun Associates, 2001). Their evaluation focused on three specific strategic goals: enhancing the curriculum, professional development and community engagement. Their survey results showed that there was still limited use of ICT by many teachers in their schools. This was partly attributed to lack of expertise of teachers to use different types of ICT resources, lack of pedagogical knowledge about how to use ICT in the curriculum and limited engagement with the wider community. For those teachers who did use ICT in their teaching, it was mainly limited to using email and word processing. The main reason for moving to Thin Client technology was to try and achieve more standardisation across the services they provided so that teachers would be more likely to use ICT regularly. (It is worth noting here that tightly managed Fat Client solutions can also provide similar standardisation.)

Another study conducted by the Australian Capital Territory also surveyed the existing needs of its teachers to identify the gaps in current uses of ICT and how moving to Thin Client technology might help fill those gaps (ACT, 2005). Some of the gaps which they had identified in their study were the patchy and limited use of ICT in different curriculum areas, inadequate expertise of the teachers to select and use ICT resources and the lack of community access to link with the work of schools. They found that by changing to Thin Client technology they could provide more terminals for a similar previous budget and provide more uniform provision across different curriculum areas. The teachers would not need such extensive IT skills because all the terminals would have the same presentation and user interface, and there were enough resources to be able to provide some Thin Client terminals in local community centres such as libraries and youth centres.

The literature reviewed here includes the earlier more substantial work of research into the use of computer networks in general to promote curriculum development in schools (Vescoukis and Retalis, 1999; Crawford, 2003). This showed how networks in general can encourage student communication, sharing of resources, communicating with the teachers and generally extending the school curriculum. These findings have implications for Thin Client networks because they enable schools to acquire larger numbers of terminals, thereby widening access and potentially extending the scope identified by Vescoukis and Retalis and Crawford in the uses of ICT within a school.

3.5.3 Learner contribution and access beyond the classroom

A significant development over the last ten years has been the use of ICT which facilitates students making contributions to the work of their colleagues and sharing their learning experiences (Watson and Andersen, 2003; Cox and Abbott, 2004). This is done through online courses, through emailing draft homework to the rest of the class, through project work and through the use of Virtual Learning Environments. A requirement if students are to be able to pick up on their studies wherever they are, is that they can access the same files and use the same applications whether they are working at school, in a media centre or at

home. The case studies discussed above on widening access provide encouraging evidence about the use of ICT across the school–home divide which has been supported by Thin Client technologies. One of the benefits of using the same technology at home and at school was that pupils did not have to adjust to using a different interface.

In Pearson's study (2003) the author found that when 10-year-old children were using the internet at home they did not distinguish between resources held on local machines, those on the school network and those on the internet itself. The pupils were often more concerned about protecting their own data rather than being able to find much more information. This implies that familiarity with the client device and the applications available across different devices may be an important consideration in supporting learning at home and school. Other studies have also reported on the links between using different client devices (in the computer laboratory, internet café and at home) during the course of educational activities (Watson and Andersen, 2002), and the need for a range of different types of networks to support emerging distance learning (Tellerup and Helms, 2002). Although there is now a substantial body of knowledge about ICT contributing to the autonomy of the learner, the Thin Client studies have not reported on how learning can be supported across different types of Thin or Fat Clients and where the limitations may lie.

3.5.4 Autonomy of the learner

One of the claims which is made about students having access to the vast body of information over the internet and individual access to a computer is that they can take more responsibility for their individual learning (Pearson, 2003; Cox and Abbott, 2004). Working away from the classroom on their own results in students becoming apprentices, learning new skills and working asynchronously with their teachers. An important educational policy at present is personalised learning, and some of the above arguments for Thin Client technology support this policy because of the possibility of widening access and ICT being available at any time and anywhere. The case studies discussed above, which reported on providing Thin Client terminals in some pupils' homes, show that an important benefit to individual pupils of widening access to ICT both at school and at home is that every child can have regular access to the school network and furthermore be able to obtain support from teachers and fellow learners. It is not clear from the studies reported here in the literature review whether the Thin Client school servers also support Fat Clients, which is the case of the hybrid systems used in many universities, in which the main servers can also be accessed over the Web as well as through Thin Clients on site, in which case facilities such as courses run in Virtual Learning Environments can support the learner outside the university environment. However, as is shown in the Project Review (see Section 4) several schools are also using hybrid systems to make use of legacy machines.

In many cases the extended access to the main school server from home will provide opportunities for older pupils to be more autonomous and take more responsibility for their own learning. However, according to a study of 10-year-old school children by Pearson (2003) the role of social collaboration both with siblings and parents when the pupils were involved in web searching was very important in guiding productive learning. There is a large body of academic literature on the importance of both enabling pupils to become more autonomous but also on the benefits of group and other learning settings. (see for example, Eraut, 1995; Crook, 1998; Harrison *et al*., 2002). This research shows that the autonomy of the learner when he or she works on his/her own needs to be balanced with the collaborative activities which can also lead to enhanced learning of each child. The most immediate contribution which Thin Clients can make is through the larger numbers of terminals possible within the school budget which will enable pupils to use them at school in a larger number of

locations outside the computer laboratory or classroom, at the end of the school day and in school breaks.

Early on in this report it was argued that other technologies have influenced the ways in which teachers organise their teaching. One of the benefits of having fewer ICT resources in the past has been that this has encouraged group work using ICT and whole-class teaching, both of which have been shown to enhance learning (Crook, 1998; Harrison *et al.,* 2002). When PC networks were introduced into schools there was a move by teachers to organise the students to one per computer because they believed that ICT was mainly for individualised learning (Watson, 2001). It would be detrimental (though by no means a certainty) if Thin Client technology were to drive teachers towards focusing only on individual learning and study, thereby losing the opportunities which collaborative learning can bring to education. Previous research into teachers' understanding and expertise in using ICT resources appropriately (which includes Thin Client networks) shows that there is still limited use made of collaborative opportunities (Watson, 2001; Cox and Webb, 2004).

3.5.5 Impact on the curriculum

Although there is insufficient research to date about the impact which Thin Client technology may have on the school curriculum, the evidence from the literature reviewed here, which includes widening access and increasing the independence of the learner and the links between home and school, implies from previous studies that Thin Client technology could have a significant impact on the curriculum. The most frequent benefit reported by teachers was that it made ICT easier for them to use and they had more confidence in its use. Since these are two important enablers in the use of ICT (Preston *et al*., 2000; Scrimshaw, 2004) Thin Client networks (because they appear to enable the schools to increase significantly the number of terminals) should enable many more teachers to make regular use of ICT in their teaching. Given the appropriate professional development for the teachers, this should have a significant impact on the delivery of the curriculum as it is enhanced through greater use of ICT.

From the above and many other publications about ICT in the curriculum, there could be extensive opportunities for Thin Client technologies to improve and extend the school curriculum. However, there may also be limitations to the range and scope of ICT uses because of the limitations to the ICT resources which might run over a Thin Client network, explained earlier. Furthermore, as explained at the beginning of this report, challenging and imaginative uses of ICT can only be achieved if teachers have the expertise and the experience to make use of the technology. Therefore teachers' professional development is a key to the successes which Thin Client technology could bring to the government's education agenda.

3.5.6 Teachers' professional development of ICT use

Some of the school cases and local authorities reviewed have discussed the need for ongoing teachers' professional development although mainly to help teachers 'get to grips' with the technology. These include those which have started with an assessment of staff ICT needs (for example, Australian Capital Territory, 2003; Derby City Council, 2004f; Sun Associates, 2001), which has included assessing the teachers' ICT skills and their training needs. The Leverstock website (Leverstock, 2006a–f) includes case studies of school experience with Thin Client systems. The general benefits reported from this type of integrated support are linked to the development of staff skills. These include: greater staff confidence and competence; ready integration of ICT into the wider curriculum, particularly used as a vehicle to support learning; reliability of the system; and rapid installation and establishment of Thin Client networks.

One component of teachers' professional development in the uses of ICT is how much technical skills they need. To some extent this depends upon the technical support available in their school but since the majority of English secondary schools have on average only one or two technicians shared between over 70 teachers (Beauchamp, 2003) teachers cannot rely on regular technical support to enable them to use ICT in their teaching. They usually have to be able to load and run software themselves, and sort out the printers and other peripherals. As shown above, the technical demands on teachers who are using Thin Clients are less than those often required for using a mixed technological resource therefore if they were only going to use Thin Client workstations this aspect of their professional development requirements would be reduced. However, as the technology changes, it would be undesirable for teachers to be limited in their ICT skills just to using a Thin Client terminal.

Unlike conventional PCs the Thin Client workstations themselves require little if any administrative support. Software applications only need installing once (or as many times as the system has servers). Use of two servers enables one to be taken off-line for software installation or other maintenance without disrupting client functionality. This means that teachers do not have to deal with problems of local computer crashes nor with failing hard drives and therefore may not need training in these skills. All of these facilities reduce some of the professional development needs. However, at the beginning of this report evidence was provided for the overriding importance of teachers' professional development to enable them to acquire the pedagogical knowledge to be able to use ICT effectively. The same arguments apply here regarding teachers using Thin Client technology. Although the researchers have reviewed a good range of school and research reports, there is little detailed evidence to date about what actually goes on in the classroom when teachers are using Thin Client technology, nor what specific opportunities it has for raising standards and improving pupils' achievements. However, since as said earlier, there is 30 years' evidence that, with the appropriate professional knowledge and skills, teachers can harness ICT to improve students' learning (Harrison *et al*., 2002; Cox and Webb, 2004) the same arguments apply to Thin Client technology. Teachers may need less professional development in using the technology from a technical perspective but they will still need the same range of professional development experiences to know how to select and use it appropriately.

3.6 Advantages and disadvantages of Thin Client technology

The literature and school reports reported on in this literature review have revealed both advantages and disadvantages to using Thin Client technologies in schools which are summarised below.

3.6.1 Thin Client costs

There are clearly major budget implications associated with any decisions made by schools and/or local authorities about the technology that is most likely to fit their specifications. Such costs relate not only to the capital funding required for purchase of hardware, software and installation, but also to the rising costs of servicing, maintenance and security. According to Banbury and Brown (2001) there are a number of concerns which need to be addressed when deciding whether or not to move to Thin Client technology. Firstly, the initial costs of implementing Thin Client technology can be quite high, especially if the network infrastructure needs upgrading to cope with the greater dependency on the network for speed, capacity and reliability. Banbury and Brown also state that savings on the cost of hardware is ‘one of the great myths of thin-client networking’. Decision-makers should not expect up-front savings, rather a containment of management and support costs over time. The evidence collated here suggests that there could be some distinct cost advantages in some elements of the total costs of ownership, as reported in the previous sections.

Cost advantages

- Less expensive terminals: Thin Client workstations (terminals) can be cheaper to purchase than PCs.

- Use of legacy equipment: older hardware could be reused. For example, old PCs could be added to a Thin Client network thereby increasing the number of terminals available. This also helps reduce costs by extending the lifetime of the PCs themselves and reducing the need to purchase additional terminals.

- Reduced downtime: savings were reported on the reduced downtime which occurred with Thin Client servers, which meant less time wasted on sorting out the technology.

- Reduced expenditure on software installation and upgrades: these costs can also be less because only the software on the server needed to be installed and upgraded, therefore the time to upgrade as well as the expenditure on purchases was reduced.

- Reduced support and maintenance: the cost of technical support and maintenance can be less because the Thin Clients needed very little maintenance, and the work can be done centrally. Technicians could even be shared across sites and institutions.

- Reduced long-term hardware costs: longer term costs for replacing hardware can be reduced because of the reasons given above. According to Banbury and Brown (2000) there can be a lifetime reduction obtained because it is expected that the terminals will last much longer.

There are also many hidden cost benefits identified. These include the costs of teachers' time when computers and networks are not working, which occurred more frequently with Fat Client networks. The evidence from the Thin Client study here is that if teachers' time spent on having to sort out local hardware and software problems and also reorganise disrupted lessons is calculated, this would be a significant saving.

Cost disadvantages

- Software expenditure: software licence costs can be increased with the larger number of workstations (but no higher than a similar Fat Client network).

- Higher specification servers: appropriately configured Thin Client networks typically require higher specification servers and more of them than the equivalent Fat Client network.

3.6.2 Thin Client management, maintenance and support

Other advantages have been identified regarding the way in which Thin Client networks are managed because of their centralised architecture. Some Thin Client terminals have no disk drives and virtually no moving internal parts, so there is very little that can go wrong. They can also be simpler to use. These benefits should mean less work for system administrators who provide ICT support. Almost all maintenance is done at the server end, which greatly reduces the time spent fixing hardware failures and software conflicts at user workstations, especially those in remote locations. In principle, only the server should need updating to accommodate more powerful software, whereas with Fat Clients the machines can become obsolete in two to three years. Many schools and other organisations manage on much older workstations, where replacement cycles are more in the region of three to five years, however. The main advantages and disadvantages are summarised below.

Advantages

- Centralised management, maintenance and support: most of this can be done centrally which can help schools secure greater control and standard of service. It should be simpler to provide the clients with up-to-date software because this only needs to be provided by the server. Problems can be sorted out quickly because the solution is applied across the whole network at once.

- Version control: Thin Client networks prevent users storing different versions on local PCs. This can make it easier for the teacher to ensure that all users are using the same version. (If local disk drives are locked down on a Fat Client network, or shared network drives are used, this benefit may also be true of Fat Client networks.)

- Data security and integrity: this is improved because all the resources are stored and backed up centrally by default.

- Reduced threat from viruses and malicious activity: software can be managed centrally, and machines can be locked down. Virus threats and other malicious activity can therefore be managed more closely because all the resources are loaded and maintained centrally, removing the risks of viruses entering the system through individual workstations.

- More regular upgrades: these can be done more regularly because of the much shorter time involved compared with having to upgrade each individual PC on a Fat Client network. This can help reduce problems with machines not having the latest software update or patch.

Disadvantages

There are also some disadvantages for using Thin Client technology with a centrally managed system which have been identified in this review:

- Restricted functionality: with less support for removable storage, this restricts the way in which students and teachers can work with the terminals. They cannot, for example usually save and load work onto a floppy disk or CD-ROM.

- Back-up: the amount of time to back up all the software can be considerable (see for example Correia and Forman, 1998). However, this needs to be set against more complex back-up requirements of Fat Client networks, where on some systems individual machines may hold software and data.

- Licensing: 4 per cent of schools have reported that there can be substantial problems with licensing arrangements depending upon the number of active current users (though this can also apply to Fat Client solutions).

- Peripherals: there is little evidence from the review as to whether or not it is possible to connect interface boxes and sensors and switches as required in ICT, science and Design and Technology lessons.

- Limitations with graphics: there is evidence that there are problems in running more graphically challenging software such as that requiring video output, or fast moving animation.

- Flexibility: there is a loss of flexibility in the ways in which teachers can work with ICT to suit their particular need.

- Reliance on the network: even though Thin Client servers proved to be very reliable, if the servers do go down there can be indirect costs caused by having to reschedule lessons, find alternative teaching resources or cope with other disruptions caused by the network failure.

In considering the technology required to deliver teaching and learning and administration functions in schools, an assessment needs to be made about the potential facility and capacity that such technology will need to deliver such services, not just now, but in the 'predictable' future. Sampling this potential future is already possible through exploring case studies of innovative developments in education institutes both nationally and internationally and in further and higher education.

3.6.3 Widening access

Significant advantages of Thin Client technology are found in the ways in which it widened access to pupils, teachers and parents to ICT, because terminals can be cheaper and therefore more can be purchased for the same budget. These included:

- greater home access: there are still many homes in developed countries where there is no access to ICT (Vaiol, 2004), and many households in the UK still do not have a PC. As terminals cost less and are easier to support, 32 per cent of schools reported providing low-cost ICT resources to teachers and learners who previously had no access to ICT.

- greater in-school access: lower terminal costs enable schools to increase the number of terminals, so teachers and pupils have greater opportunities to use ICT in all lessons, for individual study and in other school areas for tutorials and project work. Similarly, greater provision gives schools more opportunities to support after-school clubs.

The disadvantage which might arise with Thin Client technology while widening access is that the range of educational software on such a network may be more limited than what is currently available on PCs.

3.6.4 Rationalisation and sustainability

An advantage of Thin Client technology reported by many of the schools, local authorities and universities was the rationalisation and sustainability brought about by having a uniform system with a standardisation of terminals, desktops and applications, enabling users to work confidently in any location. This was a particular strength expressed by many teachers. The disadvantage of this might be that there is less diversity of ICT resources and therefore fewer opportunities for new and exciting teaching and learning experiences. This limitation was overcome to some extent with many of the schools by either having the older software loaded onto the main Thin Client server as well as new purchases, or by maintaining a hybrid system with the older PCs keeping some of their Fat Client facilities and the software loaded and run locally.

3.6.5 Teaching and learning

There can be advantages to teaching and learning as a result of the above through a 'knock on effect'. The advantages which have been reported by teachers and schools include the following:

- Uniformity: Thin Clients were easier for teachers to use because every terminal presents the same desktop and user interface and local changes cannot be made, so teachers were more confident to use ICT once they had learnt how to use their terminal.

- Improved file sharing: there was less work involved in setting up the resources teachers needed for lessons because this had all been done centrally.

- Focus on teaching and learning: teachers' professional development could be concentrated on the pedagogical aspects of using ICT because of the reduced need to learn technical management skills.

- Extended access: students had more opportunities to work on projects once the lesson had finished because the number of terminals in general was greater and they were situated in more locations.

As explained earlier, there were some educational disadvantages reported with the present uses of Thin Client networks. It is hoped this might change as teachers learn more about how best to use ICT in their teaching.

Disadvantages

- Some software limitations: the type of software being used was largely limited to that able to run on the main server and not necessarily the most suitable for individual teaching and learning needs.

- Less flexibility: there was less flexibility in the ways in which ICT could be used in teaching because of no access to local peripherals and storage systems.

- Reliance on external bodies: teachers and schools can be influenced significantly by suppliers in the software they acquire and the ways in which they expected to use ICT over the network. This can create the possibility that teachers were leaving the education decisions to suppliers rather than determining the ICT use based on their curriculum requirements.

These are the main advantages and disadvantages identified in this literature review. The main conclusions to the whole study are discussed in Section 5.

4 Project review

This section reports on the findings of our work to establish the nature of Thin Client implementations in as many schools across England as possible, within the limitations of time and the research methodology. Analysis and conclusions are given in section 4.9.

4.1 Identification of schools

The researchers wrote to key ICT contacts in all local authorities in England, asking them to identify schools that they knew were implementing Thin Client solutions. A mass mailing was not carried out in order to reduce the burden on schools, the majority of which do not use Thin Client systems. Requests for potential leads were also placed in a range of places including Becta and Naace communication channels and on online discussion forums. A number of the suppliers contacted were interested in the Thin Client study and were keen for the work to take place. However, there was some reluctance to give a complete list of schools in some cases, mainly due to the sharing of business sensitive information that they would be supplying. When reassured that the information would be treated confidentially, suppliers agreed to share the information.

A total of 133 educational establishments were identified as being potential leads for having Thin Client networks in operation, including two in Scotland. Against over 23,000 schools, this is not a significant number. However, this approach needs to be set against the results of Becta's Local Area Network survey, in which 556 schools were asked various questions including whether they had a Thin Client network in place. This found that 9 per cent of secondary and 5 per cent of primary schools had some kind of Thin Client implementation. Nevertheless, this investigation has identified enough schools to gather a clear picture about how those schools are implementing Thin Client technology, and what the implications have been for them.

Of the 133 potential leads a total of 50 responses were received from schools and other educational establishments. A number of additional schools were identified towards the end of the project review as being potential leads and are included in the total number of leads. However, due to the limited timescale allowed for the project, not all of these schools managed to make a return.

4.2 School information

Schools that were identified as having a Thin Client solution in place were asked to complete a simple questionnaire and these were followed up with a phone call to check that the school had received the questionnaire.

Respondents were asked to provide information about their school and the Thin Client solution in place. From the 50 responses received, the following information has been drawn out.

4.2.1 Responses by school type

Of the 133 schools identified, the breakdown between types of schools is as follows.

Table 1 – Number of schools identified by type

	Number of schools identified	Percentage of responses
Primary	56	42.0
Secondary	67	50.0
Other	10	8.0
Total	**133**	**100.0**

Of these schools, 50 completed returns. Slightly fewer returns were received from the primary sector (see Table 2), but overall the number of responses from each sector was reasonable. Table 1 suggests that Thin Client technology is moderately more common in secondary schools, but a statistically valid sample would be needed to draw this conclusion.

Table 2 – Number of school responses by school type

	Number of responses	Percentage of responses
Primary	16	32.0
Secondary	29	58.0
Other (including a Technical Innovation Centre and independent schools for all ages)	5	10.0
Total	**50**	**100.0**

Table 3 – School type by status of Thin Client implementation

School type	Complete implementation	Complete removal	Partially completed implementation	Planned	Planned and supplier identified	Total
Primary	12	1	3	0	0	16
Secondary	20	1	6	2	0	29
Other	4	0	0	0	1	1
Total	**36**	**2**	**9**	**2**	**1**	**50**

Table 3 shows that the majority of respondents have a completed installation of a Thin Client network. The majority of schools (72%) have a completed Thin Client network with 4% of schools removing Thin Client altogether and 18% having a partially completed Thin Client network.

One school described the status of the Thin Client network as partially completed because a pilot Thin Client network had been set up in a special educational needs department. Another school described its Thin Client status as partially completed because they thought the network was ever changing.

Two of the respondents removed Thin Client altogether for the following reasons:

- One school found Thin Client too restrictive with graphic intensive software not working at all
- One school moved to Thin Client as part of a pilot in partnership with the local authority. The champion of Thin Client subsequently retired from the local authority, leaving the school to find support from a supplier of IT systems. Eventually the school found it was having to support itself. Ultimately the decision was taken to re-invest in a Fat Client network.

4.2.2 Duration of implementation

Table 4 below shows that over half the schools had been implementing Thin Client technology for more than two years. A significant number had recently implemented a Thin Client solution, suggesting that this technology is not waning in terms of take-up in schools – particularly secondary schools, where a slight majority of solutions were less than two years old.

Table 4 – Duration of implementation of Thin Client technology

	Less than one year	One to two years	Two to five years	More than five years	Removed / non-response
Primary	1	3	8	3	0
Secondary	6	8	6	6	3
Other	1	1	2	1	1
Total	8	12	16	10	4

4.2.3 Geographical spread

The response from schools has been thinly spread across local authorities, as Table 5 indicates. Table 5 identifies clusters of schools in Derby City, Hampshire and Nottinghamshire, suggesting that these local authorities may support the use of Thin Client technology in schools. Although a more comprehensive study would be needed to confirm this, our conversations with some of the local authorities concerned bear this out.

Table 5 – Number of responses by local authority

Local authority	Number of responses
Bath & North East Somerset	1
Berkshire	1
Birmingham	1
Bristol	1
Cambridgeshire	1
Camden	1
Cumbria	1
Derby	5
Derbyshire	1
Devon	1
Durham	2
Essex	2
Gloucestershire	1
Hampshire	4
Hertfordshire	1
Kent	2
Lancashire	2
Lincolnshire	1
Manchester	1
Milton Keynes	1
North Somerset	1
Nottinghamshire	4
Oxfordshire	1
Plymouth	2
Portsmouth	2
Reading	1
Shropshire	1
Somerset	1
Staffordshire	1
Stockton	1
Surrey	1
Tameside	1
Torbay	1
Wiltshire	1
Total	**50**

4.2.4 Type of terminals used

Table 6 – Type of terminals in use

Type of terminal	Number of responses	Percentage of respondents answering this question
Bespoke Thin Client	40	42.0
Legacy kit	29	30.0
Other PCs and laptops	25	26.0
Other	2	2.0
Total	**96**	**100.0**

Table 6 shows that schools use a variety of terminal machines, and in many cases schools made use of recycled or donated machines rather than purchasing bespoke Thin Client machines in order to keep costs down. Where classroom space is at a premium, 3% reported space saving as a benefit, 6% reported space saving as a rationale for having a mixed network and 8% reported space saving as driving factor. Bespoke Thin Client terminals combined with flat-screen monitors can save space and reduce noise and heat.

Table 7 – Number of clients per school by type

Type of terminal	Mean	Percentile 25	Percentile 75	Minimum	Maximum
Bespoke Thin Client	62	19	55	1	400
Legacy kit	58	10	85	2	220
Other PCs and laptops	79	22	78	1	350
Other	17	3	30	3	30
Total	**134**	**40**	**173**	**4**	**700**

The key point to note here is the high level of usage of legacy kit and PC terminals. The first, legacy kit, suggests that Thin Client is offering schools a way of keeping older kit in use whilst the use of PCs and laptops (particularly laptops) suggests that mobile computing is still desirable and schools are finding ways of securing this within a Thin Client architecture.

One school indicated that it only has four Thin Client terminals in total. This is due to the school piloting Thin Client in the Special Educational Needs department. The department was in need of a computer suite, and the school took the view that the most cost-effective way of doing this was to use a Thin Client solution. The member of staff in charge of the Thin Client network is hoping to extend it across the school.

Two secondary schools indicated that 700 Thin Client terminals were in use throughout the school, suggesting that the school is happy with Thin Client. Both of the schools with 700 Thin Client terminals have over 1,400 pupils, giving a pupil to computer ratio of around 2:1 – well ahead of the previous DfES target of 5:1 in secondary schools.

Table 8 – Number of servers supporting the Thin Client network per school

	Mean	Percentile 25	Percentile 75	Minimum	Maximum
Servers	6	1	7	1	45

Table 8 shows that the mean number of servers supporting the Thin Client network in use in schools is 6, while the maximum is 45. Those schools with larger number of servers use them for a variety of purposes. A large fraction is used to provide terminal services through software such as Citrix on the school network. Other uses of servers include web, email, and FTP, file storage, back-up and school administration services such as the school's management information system software.

4.2.5 Hybrid networks

Schools were asked if a separate Fat Client network was available for staff and student use.

Table 9 – Schools using a hybrid network

	Number of responses	Percentage of responses
Yes	37	74.0
No	10	20.0
No response	1	2.0
Fat client replaced the Thin Client implementation.	1	2.0
N/A	1	2.0
Total	**50**	**100.0**

Table 9 shows that the majority of respondents (74%) maintained a Fat Client network in addition to their Thin Client network (though these may be logical separations rather than physical). One school replaced the Thin Client network with a Fat Client alternative because Thin Client was found to be unsuitable for the school's needs. Reasons that were given for the use of a hybrid network can be broadly classified as follows:

- Processor and graphic-intensive applications did not work reliably on the Thin Client network in the school, which had an impact on other network users
- Administration staff in many cases used a Fat Client network, the main reason being that the staff can continue working even if the network stops working
- Many teaching staff use laptops which have offline access to data and applications which need to connect to the school network in order to get access to the internet and e-mail.

4.2.6 Operating systems in use

Server operating systems

Table 10 – Server operating systems in use

Operating system	Number of responses	Percentage of responses
Linux	10	17.2
Microsoft	38	65.5
Unix	3	5.2
Risc OS	2	3.4
NetBSD	4	6.9
Novell	1	1.7
Total	**58**	**100.0**

Table 10 shows that there were 58 responses, though there are only 50 schools that made returns. This is due to the fact that 18% of schools run multiple servers for a variety of purposes, and using different operating systems. The majority of servers were operating a Microsoft operating system with just under a quarter of schools using Open Source alternatives.

Client operating systems

Table 11 – Client operating systems in use

Operating system	Number of responses	Percentage of responses
Linux	11	25.6
Microsoft	28	65.1
Thin IT	2	4.7
Risc OS	1	2.3
OS X	1	2.3
Total	**43**	**100.0**

Again, a similar pattern is seen in the operating systems used on client terminals with the majority of schools opting for Microsoft operating systems, followed by almost a quarter of schools using an Open Source operating system.

4.3 Functionality

Schools were asked to comment on a number of areas regarding the functionality of the Thin Client network, such as its primary function within the school, any restrictions that Thin Client imposes on the use of applications, the benefits associated with Thin Client, and the reliability of the network.

4.3.1 Network uses

Respondents were asked to provide details about the uses of the Thin Client network in terms of teaching and learning and administration.

Table 12 – Uses of the Thin Client network

Network use	Number of responses
Curriculum uses	42
Administration uses	18

Of those schools that responded to this question, there were 16 schools which used a Thin Client network for both curriculum and administration while others maintained separate systems for curriculum and administration. One school has developed its own web-based management information system using an Open Source database, web server and scripting language in order to keep all systems under the same operating system.

Typical applications in use in schools that responded to the study questionnaire can be broadly classified as:

- office productivity (Microsoft and Open Source alternatives)
- internet browsing
- email
- programming
- graphics processing, such as graphics or photo editing software and some video streaming software
- educational software (particularly prevalent in primary schools).

4.3.2 Limitations and issues

The following issues were reported with Thin Client technology.

Table 13 – Issues

Issue	Number of responses
Applications	7
Peripherals	7
Multimedia	14
Other	16
None	10
Total	**54**

Other issues covered in the 16 responses from Table 13 are listed below. It is important to note that some of the issues listed are not unique to Thin Client solutions: many Fat Client solutions have similar limitations. As one school noted, 'We thought in the past there were restrictions on using some software, but…we are beginning to realise it is not a unique problem to Thin Clients.' The quotes listed below, grouped under 'other' in the table above, need to be read with this caveat in mind. They included the following:

Network issues:

- speed – can be slow at times

Security:

- still need to secure the client terminals, as they can be stolen

Software:

- uncertainty over licensing

Administration and support:

- needs a bit more organisation to set up, then it is easier
- staff training is needed.

One respondent claimed that Thin Client technology worked well from a hardware and ICT support point of view: the main issues encountered were getting educational software to work. The school also experienced difficulties in getting management and staff to accept the Thin Client technology. Staff found it difficult to comprehend the constraints such a system has on software and external hardware (USB memory sticks etc.).

4.3.3 Benefits

Table 14 – Benefits of Thin Client

Benefit	Number of responses
Ease of management	29
Cost	13
Use of legacy kit	5
Reliability	7
Security	8
Size	3
Speed	2
Other benefit	**16**

Table 14 shows the perceived benefits associated with a Thin Client network, with ease of management being cited most commonly, although by only 35% of schools. Security refers to physical security of the Thin Client devices and network security, including data integrity, threats from viruses and other malicious activity.

Though there were many other issues listed, these could be placed within the categories above it. Examples under 'other' included:

- the terminals are not desirable to thieves as they have no resale value without the server and network (a security issue)
- depreciation of Thin Client terminals is not as great as with a PC implementation as terminals tend to have a greater life span than that of a PC (a cost issue).

4.3.4 Reliability / robustness

Server

Table 15 – Server reliability

Reliability	Number of responses	Percentage of responses
Completely reliable	41	82.0
Very reliable	2	4.0
Problematic	3	6.0
Other technical problems	3	6.0
No response	1	2.0
Total	**50**	**100.0**

Table 15 shows that 82% of responses indicated that their Thin Client servers were completely reliable with 6% of respondents indicating that their servers were unreliable due to reasons that have been classified as 'other technical problems' including:

- teething problems while the system is in the process of being implemented
- slow log-on – while not necessarily attributed to an unreliable server this was considered to be a problem
- one school's belief that the network had never been set up correctly since its initial implementation.

Client

Table 16 – Client reliability

Reliability	Number of responses	Percentage of responses
Completely reliable	38	76.0
Very reliable	7	14.0
Other technical problems	2	4.0
No response or unknown	3	6.0
Total	**50**	**100.0**

Table 16 shows that 76% of respondents thought that the client terminals were completely reliable while only 10% of respondents indicated that Thin Client was generally unreliable. Some 12% of schools reported having experienced client machines failing although this was easily solved as stocks of replacement terminals were kept on site so users were generally not seriously affected by client machine failure. Some were repaired under warranty or repaired using easily replaced parts, such as a power supply.

Of the two schools that indicated that there were other problems with the client terminals, one school claimed that the terminals will sometimes turn off unexpectedly. The other school tried two types of terminal but found them both unusable.

4.4 Cost implications

Respondents were asked to provide their opinion on the cost implications of moving to a Thin Client network, broken down by overall costs (including hardware, software, support and other associated costs in setting up the Thin Client network), hardware, and software and support costs. Care needs to be taken here, as no financial evidence underpins these assertions and they may only represent the view of the respondents themselves.

Table 17 – Overall cost implication of Thin Client network

Impact	Number of responses	Percentage of responses
Costs increased	4	8.0
Costs reduced	34	68.0
Costs remained the same	10	20.0
N/A	2	4.0
Total	**50**	**100.0**

Table 17 shows the number of perceived overall cost implication of a Thin Client network. Of the four responses indicating that overall costs had increased, two schools reported that costs increased in all areas (hardware, software and support), while another school reported that the overall cost increase is due to increased support costs while other areas reduced costs or remained the same.

Of the 34 schools which reported that their **overall** costs had reduced, three schools reported that there had yet been increases in software costs while support and hardware costs had decreased. One of the schools reporting reductions in overall costs had seen increases in support costs while hardware costs had reduced and software remained the same.

The two N/A responses come from the schools that are planning to implement Thin Client or have removed Thin Client.

One school took the decision to move to Thin Client in order to save money while it was operating in a deficit budget. In one case the decision was made to implement an Open Source system as significant cost savings could be made in terms of the initial cost of purchasing the software and licensing. Other savings were made by using recycled equipment donated by local companies and the local authority. This suggests that cost reductions can be achieved in the majority of schools implementing Thin Client technology, although it is important to note that Open Source software and donated PCs can be used in non-Thin Client networks. The following tables illustrate where these reductions can be achieved.

4.4.1 Hardware

Table 18 – Impact of Thin Client on hardware costs

Impact	Number of responses	Percentage of responses
Costs increased	3	6.0
Costs reduced	32	64.0
Costs remained the same	14	28.0
N/A	1	2.0
Total	**50**	**100.0**

Table 18 shows that the majority of schools had managed to reduce hardware costs by moving to a Thin Client network. Cost reductions are possibly due to the low cost of the client terminals. For example, one unit in a school could cost as little as £125 for a bespoke terminal. Those schools using donated equipment to implement Thin Client terminals have, for obvious reasons, seen significant reductions in the initial cost of the terminal hardware.

4.4.2 Software

Table 19 – Impact of Thin Client on software costs

		Costs increased	Costs reduced	Costs remained the same	N/A	Total
Type of server operating system	Both	2	2	2	0	**6**
	No response	0	0	3	1	**4**
	Open Source	0	5	1	0	**6**
	Proprietary	5	7	22	0	**34**
	Total	**7**	**14**	**28**	**1**	**50**
Type of client operating system	Both	3	1	1	0	**5**
	No response	2	5	8	1	**9**
	Open Source	0	2	1	0	**3**
	Proprietary	2	6	18	0	**26**
	Total	**7**	**14**	**28**	**1**	**50**

Table 19 shows the type of operating system in use on client and server machines and the impact of Thin Client on software costs. Over half of respondents indicated that costs had remained the same since implementing Thin Client, with 14% of schools indicating that Thin Client had increased their software costs. Those schools that used Open Source server and client operating systems either saw reductions in software costs or the costs remained the same. Where schools had decided to pay for operating systems (as opposed to switching to Open Source software) most had not reported an increase in software costs compared to their previous solution.

4.4.3 Support

Table 20 – Impact of Thin Client on support costs (internal and external)

Impact	Number of responses	Percentage of responses
Costs increased	5	10.0
Costs reduced	33	66.0
Costs remained the same	11	22.0
N/A	1	2.0
Total	**50**	**100.0**

Table 20 shows the impact of Thin Client on support costs of the Thin Client network. Some 66% of respondents indicate that support costs have reduced. A range of reasons for this is possible, though further research is needed to substantiate which reasons the schools involved thought were most important. While the literature review indicates some of the possible reasons, schools in our survey responded that:

- security updates are only necessary on the server, not on every client machine, therefore time is saved
- if a terminal fails it can easily be swapped for a functioning terminal with minimum disruption to network users.

4.5 Network support

Respondents were asked to provide details on the type of support provided to the school, whether it is provided by internal staff or external suppliers and the nature of the external suppliers.

4.5.1 Type of support offered to schools

In-house support

Table 21 – Schools with in-house support

	Primary	Secondary	Other	Total Number of responses	Percentage of responses
Yes	2	18	3	23	46.0
No	8	6	2	16	32.0
No response	1	1	0	9	18.0
N/A	4	4	1	2	4.0
Total	**15**	**29**	**6**	**50**	**100.0**

The overall response suggests that the majority of schools provide support internally by dedicated technicians or teaching staff with the necessary skills and experience. However, it is interesting to note that most primary schools did not provide in-house support, whilst most secondary schools did. This suggests that smaller institutions rely more heavily on outsourced support, generally from a private sector supplier.

External support

Table 22 – Schools with external support

	Primary	Secondary	Other	Total Number of responses	Percentage of responses
Yes	15	13	2	30	60.0
No	0	14	4	18	36.0
No response	0	1	0	1	2.0
N/A	0	1	0	1	2.0
Total	**15**	**29**	**6**	**50**	**100.0**

Again, Table 22 shows that the majority of primary schools source support externally. Around half of secondary schools source support externally, in addition to the support they provide in-house, but it is important to note that nearly half of all secondary schools responding to this question provide all support in-house. Thin Client networks can be supported by individual institutions if they have sufficient resource to dedicate to doing so.

Table 23 – External support by provider

External support	Local authority	Private	N/A	Total
Yes	3	27	0	**30**
No	0	0	18	**18**
No response	0	0	1	**1**
N/A	0	0	1	**1**
Total	**3**	**27**	**20**	**50**

Of the 30 schools that indicated that support for the Thin Client network was provided externally, three schools received support from the local authority (two secondary schools and one primary) while the majority chose to purchase support from private companies.

4.6 Remote access

Table 24 shows the number of institutions providing remote access of some sort. Nearly one quarter provide remote access, whilst a further 15% have remote access of some sort. A total of 20% are planning remote access, whist a third do not provide any remote access and have no plans to do so. The remainder did not respond to this question. As 24/7 learning increases, the percentage of schools providing remote access will also have to increase. Further work needs to be done to explore whether the schools responding thought that their choice of network solution was helping or hindering their ability to provide this service.

Table 24: schools providing remote access

Remote Access	Total	Percentage of respondents
Full access provided remotely	12	24
Access to intranet only	1	2
Staff only	4	8
Selected staff only	2	4
Remote access planned	10	20
No access provided remotely	17	34

4.7 Reasons for choosing Thin Client

Schools were asked to say why they had chosen to implement a Thin Client solution. The respondents gave a variety of responses, which included the following:

- Cost reduced, including reduced implementation costs and lower longer term running costs
- 'Future proofing' ICT
- Allowing the use of older equipment to connect to newer network
- Quick roll-out
- Increased reliability
- Scalability
- Recommended by other schools or local authority
- Trust in the company to provide successful solutions.

4.8 Future plans

Respondents were asked to comment on what plans the school had regarding Thin Client in terms of general plans but also, network expansion, network overhaul and replacing Thin Client with another form of network.

4.8.1 Network expansion plans

Table 25 – Plans to expand with Thin Client

Network extension	Total
Expand with Thin Client	37
Expand with other technology	4
No plans or capacity to expand	8
Under review	1
Total	**50**

Table 25 shows that 37 schools were considering expanding the Thin Client network while 12 schools either had no current plans to expand or were considering replacing Thin Client with an alternative solution. The high proportion of schools that are planning to expand the Thin Client network suggests that most schools with Thin Client are happy with the implementation and the technology.

4.9 Conclusions from the project review

Though this research only covers a small sample of schools implementing Thin Client solutions in the UK, the researchers are confident that the results give a strong indication of what the national picture is likely to be, as responses were received from a range of different types of schools across a wide of range local authorities.

From our sample survey, Thin Client technology was relatively evenly spread between primary and secondary schools (Table 1). A small minority of the schools in the sample survey (4%) had removed Thin Client solutions, due to various difficulties with implementation of the network. However, the vast majority had either implemented their solution successfully (72%) or had plans for further extension (6%) (Table 3). This suggests that the majority of schools are satisfied with their solution.

Many schools (30%) had made use of legacy kit in their Thin Client Network, though a large number (42%) had switched completely to bespoke Thin Client terminals on implementation (Table 6). This shows that many schools do not keep legacy kit in place when switching to Thin Client technology, possibly because the cost per terminal for Thin Client technology is attractive.

Nearly three quarters (74%) of schools used a hybrid network, offering a mixture of Thin and Fat Client solutions across their school networks (Table 9). The type of solution in place varied considerably. This shows that many schools are reluctant to switch across wholesale to Thin Client solutions, partly because of the limitations of this type of solution, summarised below.

Most schools responding (84%) used the Thin Client network for curriculum purposes, whilst a smaller number (36%) used it for administration (Table 12). Further research is needed to understand why schools prefer to keep their administration functions on a Fat Client network.

A small number of schools (12%) reported some technical problems with the servers (Table 15), though on close examination, some of these problems may be because of poor implementation of the solution. The vast majority of schools thought that their servers were very reliable (Table 15). Levels of satisfaction are even higher for reliability of the clients on the server (Table 16). This suggests a high degree of user satisfaction.

The final key finding (apart from the benefits and issues listed below) was that the majority of secondary schools provide some form of internal support (with half being completely self-supporting), whilst the majority of primary schools prefer to source their technical support externally (Tables 21 to 23).

Benefits of Thin Client technology found in project review

The following benefits were cited as being related to implementing a Thin Client solution in schools.

Ease of management and administration:

- With basic terminals and software being run centrally, it is much easier to sort out problems. Support can be delivered centrally, and it is easy and cheap to replace terminals that cease to function.
- 66% of schools reported being able to reduce costs of supporting their ICT network.

Cost:

- Two thirds of schools reported that the Thin Client solution had reduced their costs
- 30% of schools used legacy computers on their network, showing that they are able to gain value from machines that otherwise might be made obsolete. This can reduce costs over the long term.
- Thin Client terminals depreciate more slowly than Fat Client PCs, as the terminals can be kept in service for longer.

Reliability:

- Over 80% of schools reported reliable servers and 76% reliable clients
- 4% of schools had experienced client machines failing, although this was easily solved as stocks of replacement terminals were kept on site so users were generally not seriously affected by client machine failure.

Security:

- Terminals are less valuable and therefore potentially less vulnerable to theft.
- Software can be managed centrally, and machines can be locked down. Virus threats and other malicious activity can therefore be managed more closely.

Size:

- Terminals are smaller than conventional PCs and can therefore fit into classrooms where space is at a premium.

Noise and heat:

- 4% of schools reported that with fewer moving parts, Thin Client terminals are quieter and generate less heat that PCs and laptops – an important consideration in managing the classroom environment.

Speed:

- Whilst one school reported slow network speed at times, two thought that the network was faster.

Issues with Thin Client technology found in the project review

A range of limitations for Thin Client solutions were listed. The vast majority of limitations are not unique to Thin Client solutions – they tend to be limitations of network computing, or of Open Source software solutions. However, there are some issues that seem to be commonly associated with Thin Client solutions.

Network:

- Speed: 3% of schools reported that the network can be slow during peak usage.

Peripherals:

- Some terminals lack USB ports and other ways of attaching devices, and this limits the use of peripherals such as digital cameras and data loggers.

Software:

- Processor and graphic-intensive applications did not work reliably on some Thin Client networks, and could have an impact on other network users. (However, 16 per cent of schools still reported using a range of graphics software successfully on a Thin Client network.)
- 8% of schools reported difficulty in getting educational software to work.

Hardware:

- Delivery of applications that require the user to load a CD or use a USB device caused problems.
- Use of interactive whiteboards also proved problematic on some networks.

Reliability (though the responses here need to be set against the 80 per cent plus that found the network and hardware reliable):

- 2 per cent of schools reported some unreliability of terminals, with unexplained power-downs.
- Administration staff in many cases used a Fat Client network, the main reason being that they can continue working even if the network stops working.

Security:

- There is still a need to secure the client terminals.

Licensing:

- Schools were uncertain over how many licences are needed for the network and users.

Staff acceptance:

- Staff training is required and it can take time for staff to build an understanding of the system.

5 Conclusions

5.1 Limitations of the study

As was outlined in the Project Review section, only a sample of schools implementing Thin Client technology was identified. The schools that responded to the questionnaire issued did so out of choice, and the research did not look at schools that chose not to implement Thin Client technology. However, the qualitative results that come from this small sample are thought to be sufficiently robust and revealing to merit placing some confidence in them.

The literature review has also had to draw heavily on literature from school and local authority reports including those located outside the UK, because of the paucity of studies within the UK that deal with Thin Client solutions in the education sector. Although the findings of the literature review remain valid, further research carried out in schools using Thin Client technology is needed.

5.2 Conclusions

Overall, both the literature review and the project review have identified a number of benefits and issues from implementing Thin Client solutions. These have been broken down below, covering teaching and learning; costs; management and administration; widening access; rationalisation and sustainability; reliability; security; size; noise and heat; speed and staff training and acceptance.

Teaching and learning

Advantages:

- Uniformity: Thin Clients were easier for teachers to use because every terminal presents the same desktop and user interface and teachers were more confident to use ICT once they had learnt how to use their terminal. Staff and pupils could be sure that all network resources were available everywhere on the network in the same way.
- Improved file sharing: there was less work involved in setting up the resources teachers needed for lessons because this had all been done centrally and therefore it was more reliable than with their previous experience of Fat Client networks.
- Focus on teaching and learning: teachers' professional development could be concentrated on the pedagogical aspects of using ICT because of the reduced need to learn technical management skills.
- Greater access: students had more opportunities to work on projects once the lesson had finished because the number of terminals in general was greater and they were situated in more locations due to the ability to put in place more terminals for the same budget.

Disadvantages:

- Some software and hardware limitations: the types of software being used was largely limited to that able to run on the main server and not necessarily the most suitable for individual teaching and learning needs. Also, 12 per cent of schools reported that their Thin Clients could not handle peripherals such as digital cameras or memory sticks. This too can alter the way in which teachers make use of ICT in their lessons. Further work is also required to explore whether wireless technology operates effectively with Thin Client technology.

- Graphic-intensive requirements: there is evidence that there are problems in running more graphically challenging software such as that requiring video output, or fast moving animation.

- Reliance on external bodies: teachers and schools can be influenced significantly by suppliers in the software they acquire and the ways in which they expect to use ICT over the network. This can create the possibility that teachers were leaving the education decisions to suppliers rather than determining the ICT use based on their curriculum requirements.

- Split networks: as noted below, 10 per cent of schools reported keeping the administrative network on a Fat Client basis. This could cause difficulties for teachers in accessing administrative data from their Thin Client terminal.

In any consideration of the technology required to deliver teaching and learning (and administration functions) in schools, an assessment needs to be made about the potential facility and capacity that such technology will need to deliver such services, not just now, but in the 'predictable' future. Sampling this potential future is already possible through exploring case studies of innovative developments in education institutes both nationally and internationally and in further and higher education.

Cost

Advantages:

- Reduced cost: 68 per cent of schools in the project review reported that the Thin Client solution had reduced their costs. This is in part because Thin Client workstations (terminals) were cheaper to purchase than PCs.

- Use of legacy equipment: 30 per cent of schools in the project review used legacy kit on their network, showing that they are able to gain value from machines that otherwise might be made obsolete.

- Cheaper support and maintenance: technical support and maintenance can be reduced because the Thin Clients needed very little maintenance, and the work can be done centrally. Technicians could even be shared across sites and institutions.

- Lower costs of purchase: Thin Client terminals can be cheaper to purchase than PCs.

- Lower costs of maintenance: the maintenance costs can be less because mostly only the server needed to be maintained.

- Reduced downtime: savings were reported on the reduced downtime which occurred with Thin Client servers, which meant less time wasted on sorting out the technology.

- Lower costs of software installation and upgrade: installation and upgrade costs can also cheaper because only the software on the server needed to be installed and upgraded, therefore the time to upgrade as well as expenditure was reduced.

- Hardware replacement: longer term costs for replacing hardware can be reduced because of the reasons given above. According to Banbury and Brown (2000) there can be a lifetime reduction obtained because it is expected that the terminals will last much longer.

Disadvantages

- Software licence expenditure: expenditure on software licences can be high with the larger number of terminals, but no higher than a similar Fat Client network.

- Reliance on the network: even though Thin Client servers proved to be very reliable, if the servers do go down, the system goes down. There is no scope for local working, unless higher specification PCs can operate as stand-alone machines. System failure can give rise to indirect costs caused by having to reschedule lessons, find alternative teaching resources, and delay teaching and administrative activities.

- Higher specification servers: appropriate servers can be more expensive than the usually lower specification Fat Client servers, and Thin Client networks generally require more servers than the equivalent Fat Client network. In addition, schools may need more Thin Client servers to support the same number of terminals.

Ease of management, administration and support

Benefits:

- Ease of support: with basic terminals and software being run centrally, it is much easier to sort out problems. Hence, 58 per cent of schools reported greater control and a more reliable service compared with their previous Fat Client solution. It should be simpler to provide the clients with up-to-date software because installations and updates only need implementing on the server.

- Version control: Thin Client networks prevent users storing different versions on local PCs. This can make it easier for the teacher to ensure that all users are using the same version. (If local disk drives are locked down on a Fat Client network, or shared network drives are used, this benefit may also be true of Fat Client networks.)

- Data integrity and security: this may also be improved because the data is stored on the server and backed up by default, rather than on a local hard drive which is harder to back up. (This benefit is also true of Fat Client networks where storage is done on a central file server.)

- Speed in solving technical problems: these can be sorted out quickly because the solution is applied across the whole network.

- Regular upgrades: centralised management of the network means that upgrades can be done more regularly because of the much shorter time involved compared with having to upgrade each individual PC on a Fat Client network.

- Reduced support needed for client devices: as there is less to go wrong on a client device and they cannot be altered by the user, less support is required, and terminals can simply be replaced when they go wrong. This saves time for the administrative support and for teachers themselves;

Disadvantages:

- Limited flexibility: with no local input and output devices this restricts the way in which students and teachers can work with the terminals. They cannot, for example save and load work onto a floppy disk or CD-ROM.

- Back-up: the amount of time to back up all the software can be considerable (see for example Correia and Forman, 1998). However, this needs to be set against more complex

back-up requirements of Fat Client networks, where on some systems individual machines may hold software and data.

- Licensing: 4 per cent of schools reported that there can be substantial problems with licensing arrangements depending upon the number of active current users (which is exacerbated if more terminals are in place, though not unique to Thin Client networks).
- Limitations on using peripherals: there is little evidence from the review as to whether or not it is possible to connect up interface boxes and sensors and switches as required in ICT, science and Design and Technology lessons, or using assistive technology for learners with special needs.
- Limitations with graphics-intensive software: there is evidence that there are problems in running more graphically challenging software such as that requiring video output, or fast moving animation.
- Reduced flexibility: the restrictions on local input and output devices may limit the ways in which teachers can work with ICT to suit their particular needs.

Widening access

Advantages:

A very significant advantage of Thin Client technology was the ways in which it could help to widen access to pupils, teachers and parents to ICT. This included:

- greater home access: there are still many homes in developed countries where there is no access to ICT (Vaiol, 2004), and many households in the UK still do not have a PC. As terminals cost less and are easier to support, 32 per cent of schools have been able to provide low-cost ICT resources to teachers and learners who previously had no access to ICT.
- greater in-school access: lower terminal costs enable schools to increase the number of terminals, so teachers and pupils have more opportunities to use ICT in more lessons, for individual study and in other school areas for tutorials and project work. Similarly, greater provision gives schools more opportunities to hold after-school clubs.

Disadvantage:

- Software limitations: in the literature review, we found schools reporting that the range of educational software may be more limited than that previously available on PCs (though this depends on the nature of the solution and the school's approach to software procurement).

Rationalisation and sustainability

Advantages:

- Uniformity: a uniform system with a standardisation of terminals, desktops and applications enables users to work confidently in any location. This was a particular strength expressed by 8 per cent of schools.
- Energy saving: Thin Clients are able to use less power than Fat Clients, because the terminals have fewer parts and do less work.
- Sustainability: the use of legacy machines as Thin Client terminals means that 10 per cent of schools reported being able to reduce their spend on hardware over time.

Disadvantage:

- Less diversity: if a school does not keep the software it had previously on its Fat Client architecture, there can be less diversity of ICT resources and therefore fewer opportunities for new and exciting teaching and learning experiences. This limitation was overcome to some extent with many of the schools by either having the older software loaded onto the main Thin Client server as well as new purchases, or by maintaining a hybrid system with the older PCs keeping some of their Fat Client facilities and the software loaded and run locally.

Reliability

Advantages:

- Reliable servers and clients: over 80 per cent of schools in our project review reported reliable servers and clients.
- Ease of replacement: where schools reported terminals failing, they also noted that it was easy to replace them as stocks of replacement terminals were kept on site (possible due to the low cost of terminals).

Disadvantage:

- Split networks: 10 per cent of schools reported keeping the administrative network on a Fat Client system, to ensure it could still be used if the Thin Client network went down. This could cause difficulties for teachers in accessing administrative data from their Thin Client terminal and also be a disadvantage for teaching.

Security

Advantages:

- Reduced value: terminals are less valuable and therefore potentially less vulnerable to theft.
- Reduced threat from viruses and malicious activity: because software can be managed centrally and patches and updates can be carried out on the whole system via the central servers, virus protection can be managed more closely. In addition, because machines are locked down by default with no local storage, there is little risk of viruses entering the system through individual bespoke Thin Client terminals.

Disadvantage:

- Uploading of software: the downside to this secure environment is that it can take time for new software to be loaded onto the network, which can be frustrating for teachers' creativity.

Size

Advantage:

- Terminals are smaller than conventional PCs and can therefore fit into classrooms where space is at a premium.

Noise, heat and energy

Advantage:

- Some 4 per cent of schools reported that Thin Client terminals are quieter and generate less heat that PCs and laptops – an important consideration in managing the classroom environment. Thin Client terminals also generally use less power than Fat Client PCs.

Use of laptops

- An institution running a Thin Client network may wish to have Fat Client laptops for use offline. Becta (2005b) suggests these should run a 'terminal emulation' program to act as a Thin Client whilst wired to the network. This can lead to user confusion as the user may require a different log-in procedure depending on whether the device is connected to the network or not, and therefore care must be taken to ensure that users understand the log-on procedures required. The Case Study research will examine how schools have handled this issue.

Speed

- Whilst one school in the project review reported slow network speed at times, two thought that the network was faster. Further research would be needed to investigate in detail whether network speeds are favourable over a Thin Client network, and the circumstances in which they are not. Further research is also needed to explore how Thin Client networks can take advantage of wireless technology.

Staff training and acceptance

Advantage:

- Increased confidence: as there is no variation between terminals, once teaching staff are familiar with the system, they can be more confident in using it in their classes.

Disadvantages:

- Training needs: switching to a Thin Client system requires an element of staff training, for which time needs to be set aside (as is true when introducing any new system).

- Acceptance: one school experienced difficulties in getting management and staff to accept the Thin Client technology. Staff found it difficult to comprehend the constraints such a system may have on software and external hardware.

5.3 Areas for further research

From our literature review and project review, a range of areas for further research have been identified. In general terms, the limited sources compared with other published research into the uses of ICT in education confirm that there will be a need for further research in this area once more institutions have taken up Thin Client technology.

More immediately, research is needed to clarify the points outlined below.

Teaching and learning:

- There is a requirement to teach measurement and control in the national curriculum connecting sensors and switches to computers. This can be difficult to achieve with some Thin Clients. This is an area which needs substantial further research.
- There is a need to understand better how teachers and head-teachers' pedagogical knowledge influence their choices of educational software and ICT resources in general. The limited evidence here implies that even if the teachers and head-teachers do have sound pedagogical content knowledge about the use of ICT in education, it was not evident in their reasoning for choosing Thin Client networks.
- There is a need to understand whether any of the limitations of Thin Client technology listed above restrict the way in which teaching and learning using ICT is carried out within schools.
- Further research needs to be conducted into how Thin Client technology will affect teachers' pedagogies and practices because of the limitations imposed regarding more restricted access to rich media and peripheral devices. Do these change the ways in which ICT is used in their curricula and in their choices of activities? Do they feel controlled in their uses of ICT and become less motivated to try new activities, etc.?
- Greater clarity on the drivers for adoption of Thin Client technology would also help policy makers when considering future initiatives and advice and guidance.

Costs:

- Some 66 per cent of respondents in the project review indicated that support costs have reduced. A range of reasons for this are possible, so further research is needed to substantiate which reasons were most important.

Management and administration:

- Research would clarify why some schools keep their administration on a separate Fat Client network.
- There is a need to understand why so many schools opt for hybrid Thin and Fat client systems.

Access:

- As 24/7 learning increases, the percentage of schools providing remote access will also have to increase. Further work needs to be done to explore whether the schools responding thought that their choice of the Thin Client network solution was helping or hindering their ability to provide this service.

6 Appendices

6.1 Appendix 1 – References

Australian Capital Territory (2003), *Australian Capital Territory (ACT) learning technologies Planning and Implementation Guide*: DRAFT Version 3.11

Banbury, J. and Brown, (2000), *Fat or thin? Is the verdict in?* University of Flinders, Australia.

Barking and Dagenham (2005a), Barking and Dagenham LEA Five Year Strategy. http://www.bardaglea.org.uk/testbed/tb-about-lea.cfm

Barking and Dagenham. (2005b), ICT Test Bed Project. http://www.barking-dagenham.gov.uk/9-cias/ict-team/ict-team-testbed.html

Beauchamp, A.P. (2003), An Investigation into IT in the Secondary School Curriculum: Servant or Subject? Doctoral Thesis. University of London

Becta (2004), *A review of the research literature on the barriers to the uptake of ICT by teachers*. Becta. Coventry.

Becta (2005a), *Technical Specification – Institutional Infrastructure*. Becta. Coventry

Becta (2005b), *Functional Specification – Institutional Infrastructure*. Becta Coventry. England

Becta (2005c), *Content Advisory Board. Report to the Secretary of State, No. 3*. Becta. Coventry

Becta (2005d), *Open Source Software in Schools. A Study of the spectrum of use and the related ICT infrastructure costs*. Becta. Coventry

Becta (2006), *Thin Client Technology in Schools*:*Case study analysis* Becta Coventry

Bedfordshire Local Authority (2006a), Asset Management Plan for Schools http://www.bedfordshire.gov.uk

Bedfordshire Local Authority (2006b), ICT for Learning and National Grid for Learning Strategy. http://www.bedfordshire.gov.uk

Bedfordshire Local Authority (2006c), LEA Statement of Priorities, 2003-2007. http://www.bedfordshire.gov.uk

Bristol University (2006), Information Services Access Policies http://www.bris.ac.uk/is/locations/accesspolicies/

Computer Weekly (2002), 'Cost effective IT: Dundee City Council'.

Correia, E. J. and Forman, P. P. (1998), 'Finding Wisdom in 'Dumb' Terminals'. *Reseller News*. 815.

Cox, M.J. (1983), 'Case Study of the Application of Computer Based Learning' in Rushby, N.J. (Ed.), *Computer Based Learning - State of the Art Report*. Pergamon, pp. 31-46.

Cox, M.J. (1999), 'Using Information and Communication Technologies (ICT) for pupils' learning' in Nicholls G. (Ed.), *Learning to Teach*. Kogan Page. pp.59-84

Cox M.J. (2004), 'Why E-learning credits are not working'. Keynote presentation at the ACITT National Annual conference. Coventry. July

Cox, M.J. (2005), 'Educational Conflict: the problems in institutionalizing new technologies in Education' in Kouzelis, G., Pournari, M., Stoeppler, M., Tselfes, V. (Eds.), *Knowledge in the New Technologies*. Peter Lang. ISBN 3-631-53782-4 March. Pp. 139-165

Cox, M. J. and Abbott, C. (2004) ICT and attainment: a review of the research literature, Coventry and London, British Educational Communications and Technology Agency / Department for Education and Skills.

Cox, M. J. and Webb, M. E., (2004), *ICT and Pedagogy: A Review of the Research Literature*, Coventry and London, British Educational Communications and Technology Agency / Department for Education and Skills.

Crawford, K. (2003), 'Co-operative networks enables shared knowledge: Rapid dissemination of innovative ideas and digital culture' in Marshall, G. and Katz, Y. *Learning in school, home and community: ICT in early and elementary education*. Kluwer Academic Publishers.

Crook, C. (1998), 'Children as computer users: the case of collaborative learning.' *Computers & Education* 30(3/4): 237-247.

Davis, N. and Niederhauser, D.S., 'Socio-Cultural analysis of Two Cases of Distance Learning in Secondary Education'. *Education and Information Technologies*. 10:3 pp. 249-262

Derby City Council (2003a), 2003-2008 School Organisation Plan. Derby City Council. http://www.derby.gov.uk/NR/rdonlyres/F9860265-23DD-4090-95BB-CFF6E8B51992/0/AssetManagementPlan_school_org_plan.pdf

Derby City Council (2003b), 2004-2005. Asset Management Plan – Statement of Priorities. Derby City Council. http://www.derby.gov.uk/NR/rdonlyres/A8422B83-B04E-4A76-A7B1F50F8BD38307/0/AssetManagementPlan_DerbyCityCouncilStatementofPriorities0405Final_205.pdf

Derby City Council (2004c),. 2004-2005, Asset Management Plan – Local Policy Statement. Derby City Council. http://www.derby.gov.uk/NR/rdonlyres/C3F7CC90-DB00-4429-AD87-DE9137525422/0/AssetManagementPlan_DerbyCity0405AMPLPS.pdf

Derby City Council (2004d), 2004-2006 ICT Strategy. Derby City Council. http://www.derby.gov.uk/

Derby City Council. (2004e), Building Schools for the Future and Secondary Diversity and Specialism: Joining up Local Ideas, Planning and Funding. Derby City Council. http://www.derby.gov.uk/NR/rdonlyres/22D868C1-E8B1-4817-8259-E0F0318E8C98/0/BSFClusters.pdf

Derby City Council (2004f), 2004-06 ICT Strategy 2004-2006. http://www.derby.gov.uk/NR/rdonlyres/6BEC8395-0FD9-49CC-8F64-804D6CBCB644/0/CIT_ICTStrat0406.pdf

Derby City Council (2006), ICT Policy Template. Derby City Council. http://www.derby.gov.uk/

Derbyshire County Council (2004), Derbyshire CC Asset Management Plan. http://www.derbyshire.gov.uk/education/educ_plans_and_policies/asset_management_plan/

Design Council (2005), *Learning Environments Campaign Prospectus – from the inside looking out*. Design Council. http://www.designcouncil.org.uk

DfES and PfS (2004), *DfES Building School for the Future – Key Performance Indicators for the National Programme (Joint Venture Agreement with PfS).* DfES and PfS

DfES (2003a), *Towards a Unified e-learning Strategy*, Department for Education and Skills

DfES (2003b), *'Fulfilling the Potential' – Transforming Teaching and Learning Through ICT in Schools*. Department for Education and Skills.

DfES (2004a), *ICT in schools Survey: Research information*. Department for Education and Skills.

DfES (2006), *Budget to Drive Classroom Learning Revolution*. Department for Education and Skills. http://www.dfes.gov.uk/pns/DisplayPN.cgi?pn_id=2006_0042

EmBoot Inc. (2005), Queensbridge Education Authority. http://www.emboot.com/products_SimplyRDP_Solution_Queensbridge.htm

Eraut, M. (1995), 'Group work with computers in British primary schools', *Journal of Educational Computing Research* 13(1): 61-87.

Eurydice European Unit (2004), *Key Data on Information and Communication Technology in Schools in Europe*. Eurydice European Unit

Harrison, C., Comber, C., Fisher, T., Haw, K., Lewin, C., Lunzer, E., McFarlane, A., Mavers, D., Scrimshaw, P., Somekh, B., and Watling, R., (2002), *ImpaCT2: the impact of Information and Communication Technologies on Pupil Learning and Attainment*, Becta.

Ho, M., Pratt, J.C. and Round, A. (2005), *Ubiquitous Access to ICT in Urban Schools of Developing Countries: Concept and Initial Project for Mexico*. University of California (Berkeley), USA

Integrex (2006), Integrex website. http://www.integrex.co.uk/specialistsolutions/ThinClient/thin_client.htm

Jamilah, R., Yusof R. and Saat, S. (1996), 'The return of computer terminals', *Network Computer* Vol.14 http://www.doc.ic.ac.uk/~nd/surprise_96/journal/vol4/rjry/report.html

Jones, G. (2004), *3D On-line Distributed Learning Environments: An Old Concept with a New Twist*. University of North Texas, North Texas, USA

Kouzelis, G., Pournari, M., Stoeppler, M., Tselfes, V. (Eds.) (2005), *Knowledge in the New Technologies.* Peter Lang. ISBN 3-631-53782-4 March

Leeds (2004), ICT and Information Management Strategy 2004-2007. Education Leeds. http://www.educationleeds.co.uk/

Leverstock. (2006a), Camden School for Girls – Case Study. Leverstock. http://www.leverstock.com/pdfs/Camden%20Case%20Study.pdf

Leverstock. (2006b), Essendon CoE School – Case Study . Leverstock. http://www.leverstock.com/pdfs

Leverstock. (2006c), Hammond Primary School – Case Study. Leverstock. http://www.leverstock.com/pdfs

Leverstock. (2006d), Kingsway Junior School, Watford – Case Study. Leverstock. http://www.leverstock.com/pdfs

Leverstock. (2006e), Milbourne Lodge Junior School – Case Study. Leverstock. http://www.leverstock.com/pdfs

Leverstock. (2006f), St Albert The Great Catholic School, Herts – Case Study. Leverstock. http://www.leverstock.com/pdfs/St%20Albert%20Case%20Study.pdf

Manchester University (2006). Thin Client Services. http://www.mcc.ac.uk/Thin/

Marshall, G. and Katz, Y. (2003), *Learning in school, home and community: ICT in early and elementary education.* Kluwer Academic Publishers.

National Curriculum (2006), The National Curriculum Website. http://www.nc.uk.net/webdav/harmonise?Page/@id=6004&Subject/@id=3331

Ofsted (1994), Information Technology in Schools: The impact of the IT in Schools Initiative 1990-1993. Ofsted. London

Ofsted (2004), 'ICT in Schools'. The impact of government initiative five years on. Ofsted. London

Osborne, J. (2006), A Case Study of deploying Cutter at Orwell High School, Felixstowe by John Osborne, Deputy Head. http://www.schoolforge.org.uk/index.php/Orwell_High_School%2C_Felixstowe

Parrs Wood Technology College (2006), Parrs Wood Technology College - School Improvement Plan 2004-2005. http://www.parrswood.manchester.sch.uk/school/policies/improveplan

Pearson, M. (2003), 'Online searching as apprenticeship: young people and web-search strategies' in Marshall, G. and Katz, Y. (Eds.) Learning in school, home and community: ICT for Early and Elementary Education. pp. 31-39.

Precedence Technologies (2006), Precedence Technologies website. http://www.precedence.co.uk/

Preston, C., Cox, M. J., Cox, K. M. J. (2000), *Teachers as Innovators: An evaluation of the motivation of teachers to use information and communications technologies*. Mirandanet/Teacher Training Agency, Croydon.

Relisys (2006), School Delivers Best Ever Results Using RELISYS Thin Client Solution. Relisys http://www.thinstore.co.uk/files/Stoke_Damerel_Case_Study.pdf

Schoolforge (March 2006), Case Studies of schools using Thin Client Technology. http://www.schoolforge.org.uk

Scrimshaw, P. (2002), *Total Cost of Ownership: a review of the literature. Research and Evaluation Series – No. 6*. Department for Education and Skills.

Scrimshaw, P. (2004), *Enabling teachers to make successful use of ICT*. Becta. Coventry.

Sun (2006), Sun Ray Appliances help provide Web-based learning environment for Georgia Schools. Http://www.sun.com/sunray/success.html

Sun Associates (2001), Yorktown Central School District: Three-Year Strategic Technology Plan. Sun Associates, North Chelmsford, USA

Surftec Ltd (2006a), Liss Infants and Junior Schools – Case Study. Surftec Ltd. http://www.surftec.com/casestudies/liss/

Surftec Ltd (2006b), Springfields School – Case Study. Surftec Ltd. http://www.surftec.com/casestudies/springfields/

Surftec Ltd (2006c), Uckfield Community Technology College – Case Study. Surftec Ltd. http://www.surftec.com/casestudies/uckfield/

Surftec Ltd (2006d), Winton School – Case Study. Surftec Ltd. http://www.surftec.com/casestudies/winton/

Surftec Ltd. (2006e), Surftec Ltd website. http://www.surftec.com

Surftec Ltd. (2006f), http://www.surftec.com/software/

Tellerup, S. and Helms, N.H. (2002), ‚Development and future of flexible distance learning in Denmark' in Watson, D. and Andersen, J. (Eds.) *Networking the Learner. Computers in Education*. IFIP pp. 106-113. Kluwer Academic Publishers.

The Cutter Project (2005a), Northampton School For Girls – Case Study. The Cutter Project. http://www.cutterproject.co.uk/Casestudies/northampton_school_for_girls.php

The Cutter Project. (2005b), Orwell High School, Felixstowe – Thin Client case study. The Cutter Project. http://www.schoolforge.org.uk/index.php/Orwell_High_School%2C_Felixstowe

The Cutter Project. (2005c), Sir Frederic Osborn School, Welwyn Garden City – Case Study. The Cutter Project. http://www.cutterproject.co.uk/Casestudies/sir_frederic_osborn_cutter_case_study.php

The Cutter Project. (2005d). *The Cutter Project*. http://www.cutterproject.co.uk/

The KDE Edutainment project (2006), Free Software for Schools. A catalog of Open Source Software for Education. http://edu.kde.org/

Vaiol, K (2004), 'Next Generation Divide, Think the gap between technology haves and have-nots has been closed? Think again'. *American School Board Journal*. Jul-04. 9

Vescoukis, V. C. and Retalis, S. (1999), 'Networked learning with user-enriched educational material'. *Journal of Computer Assisted Learning*. Vol. 15. No. 3. 211-220

Watson, D. M. (2001), 'Pedagogy before Technology: Re-thinking the Relationship between ICT and Teaching' in *Education and Information Technologies* 6(4): 251-266.

Watson, D. M. and Anderson, J. (2002), (Ed.) *Networking the Learner. Computers in Education.* IFIP. Kluwer Academic Publishers.

West Sussex County Council. (2006), ICT Strategy and Initiatives webpage. http://wsgfl.westsussex.gov.uk/ccm/navigation/category.jsp?categoryID=279704

Wilson, L.S., Breuleux, A.,Gibbons, A., and Andruske, C. (2001), *OECD/CERI ICT PROGRAMME: A Case Study of ICT and School Improvement at Crocodile Valley Secondary School (1)* British Columbia Canada. OECD/CERI