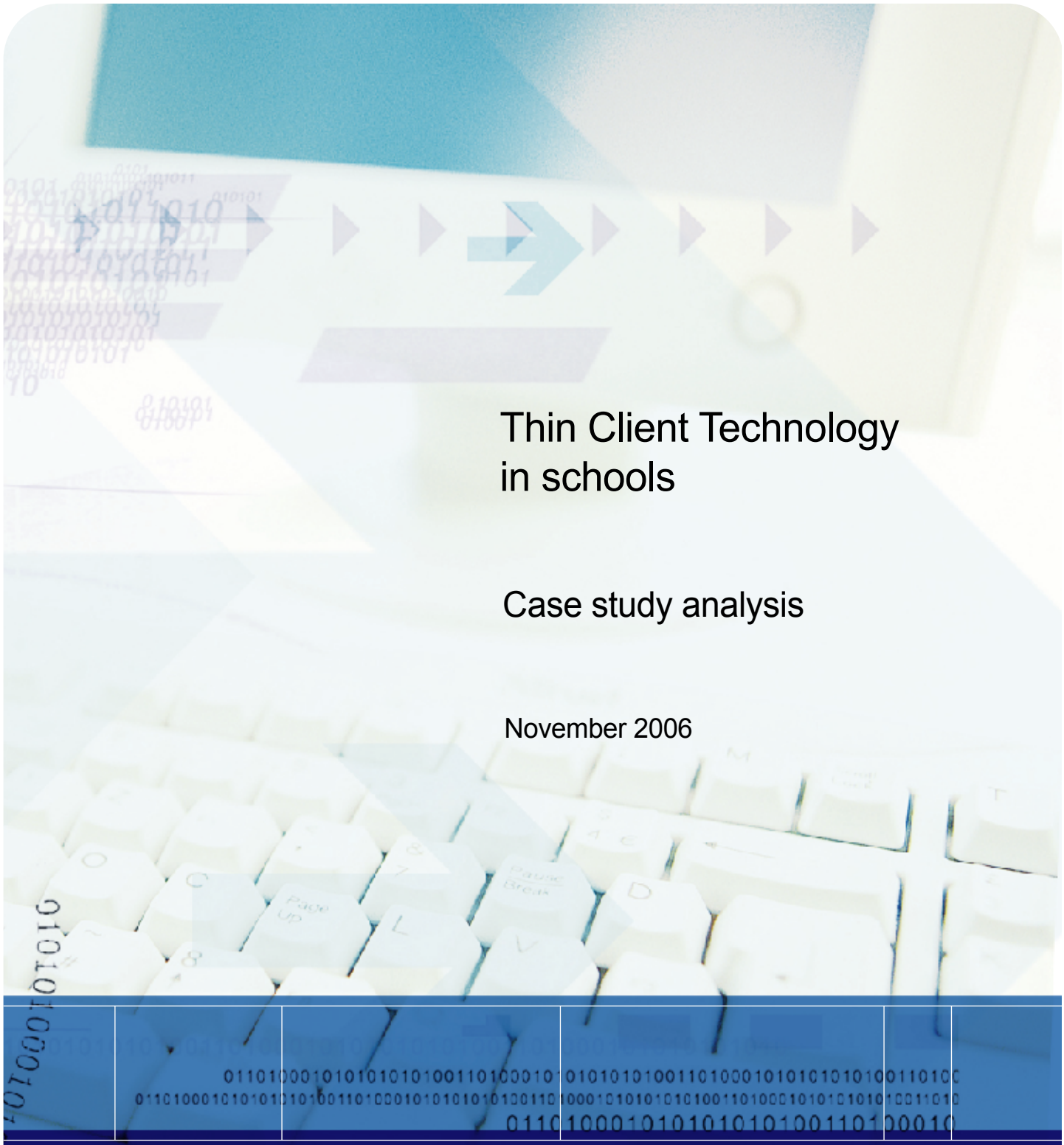

Thin Client Technology in schools

Case study analysis

November 2006

Becta
ICT Research

Contents

1 Executive summary

This report (the second in a series of two) sets out the findings from twelve case studies of schools in England that have implemented Thin Client networks. The report aims to uncover the key experiences of those schools, with a view to learning lessons and drawing conclusions for other schools considering implementing a Thin Client network, and for policy makers considering what further advice and guidance to issue.

Twelve schools using Thin Client networks were studied: four primary schools and eight secondary. None of the schools studied implemented Thin Client networks as the single network for the school: all had some form of Fat Client network or separate stand-alone machines in operation as well, whether that was for a music department, the school office or some other part of the school. This hybrid solution was put in place for one or more of a combination of reasons, outlined in more detail below. But essentially, all the schools studied retained the flexibility that a mix of Thin and Fat Clients offered, enabling the benefits of Thin Client technology to be complemented by those of Fat Client technology.

1.1 Learning and Teaching

1.1.1 Benefits

Overall, those interviewed in the schools studied pointed to five major impacts on teaching using ICT:

- Lower costs per terminal enabled greater access to ICT for the budget available. This meant better terminal:teacher and terminal:pupil ratios, which allowed more teachers to use ICT in their lessons. It also allowed teachers to use ICT more frequently in their lessons.
- Greater reliability of terminals gave teachers more confidence to make use of the network and terminals than had been the case with the schools' previous networks.
- Where schools provided remote access using Thin Client technology, this gave teachers greater flexibility of working than before the remote access was put in place (Fat Client systems can, of course, also provide remote access).
- A common and consistent software build across the school (remotely facilitated by the Thin Client centralised system) encouraged increased use of ICT by teachers from a greater number of locations.
- The quieter and cooler environment associated with Thin Client terminals has provided an environment more conducive for teaching and learning, including library locations in school.

These factors had combined to enable teachers to make more use of ICT in lessons and in the preparation of lessons, but many of these benefits may also be true of extensive and well managed Fat Client networks. However, all the schools reported that it was much more difficult to provide these benefits with Fat Clients because of the need to update and oversee all machines and software on a very regular basis.

In general, pupils were reported to have made good use of the additional technology available to them and the Thin Client systems had been well received. The overall increase in ICT resource because of the Thin Client contribution was reported by some schools to have several beneficial impacts on the pupils' attitude and learning:

- Pupils' ICT skills were reported to have improved to reach above national averages because of the regular and frequent uses of ICT.
- Pupils were able to work flexibly, especially where out of class work (home-work, self-study) was concerned because of having access to the school network from additional locations within school and often at additional times.
- Collaboration amongst pupils was reported to have increased because of the ability to collaborate outside of school hours on projects and homework.

1.1.2 Issues

A range of issues associated with the impact of Thin Client technology on teaching and learning were reported:

- Range of software: in describing their ICT uses with the Thin Client network, very few of the schools talked about a wide range of subject-specific software. As with previous network provision in schools, many teachers seemed to be guided by central policies and senior management views about what they could use and what was desirable to be used in their subject.
- Multimedia: all the schools studied had problems with delivering the full range of multimedia applications over the Thin Client network. Eleven schools retained a Fat Client network to enable staff and pupils, particularly those in music and design and technology, to take advantage of multimedia applications unable to run on the Thin Client network. Some schools were able to deliver specific applications, but if many students used the application at the same time the network performance slowed considerably. Video conferencing was also generally dealt with via a separate system.
- Problems with some software titles: several schools had anticipated being able to use all their existing software on the 'new' Thin Client network and this had been a main requirement influencing their choice of which system to acquire. However, following installation some features of the more powerful educational software applications would not run as reliably as they expected. This implies that extensive pilots and trials should be conducted first, running several Thin Client machines at the same time with such software to be able to judge if it will run on a fully operating system with many simultaneous users. In some schools particular software would not work on the Thin Client network at all.
- Some Thin Client networks and terminals do not support USB-enabled peripherals: some peripherals need USB ports to operate, and unless the Thin Client terminals have this facility, the school has to implement a hybrid system in the classroom. Six schools reported that more recently purchased Thin Client terminals were able to cater for peripherals via USB ports.
- Interactive whiteboards did not work on the Thin Client terminals in the schools studied: all schools used interactive whiteboards through Fat Client computers.

For the schools that implemented a network that delivered a standard Windows desktop environment for the Thin Client terminals, schools reported that no additional training was required and they therefore found little or no resistance to the implementation and take-up of the network. However, this finding needs to be tempered by several interviews, where teachers complained about multimedia not working and raised concerns about not having a wider range of software titles available on the Thin Client network.

1.2 Management and administration

Schools adopted a variety of approaches to administration. Ten schools said that they maintained separate administrative networks using Fat Client technology or Fat Client terminals to access the Local Authority's network. The administration functions studied fall into two types: the work done by the school's administrative staff, and the administration done by teachers and teaching assistants. The separate networks were just for the former. Even when the school had a separate system for administration, teachers prepared a lot of reports and progress monitoring on the educational network and then transferred this onto the administration network.

1.2.1 Benefits

- Two schools reported using their administrative system over the Thin Client network. In School 7, those interviewed thought that the administrative system was better and more efficient using Thin Client technology.
- Data is stored centrally by default

1.2.2 Issues

The reasons for maintaining separate Fat Client networks for administration fell into three categories:

- Compatibility: where management and administration software would not work on the Thin Client network, schools were forced to retain a Fat Client network.
- Fear of network failure: if the Thin Client network went down, those interviewed thought that the school would not be likely to lose the Fat Client network at the same time.
- Local authority systems: for some schools, the local authority ran the Management Information System and asked that schools use Fat Client computers to access the system.

1.3 Technical benefits and issues

1.3.1 Benefits

- Use of legacy computers: over half the schools studied had used legacy computers to reduce the cost of establishing the network. However, another key reason was that the legacy machines had USB ports and serial ports which, if enabled on the Thin Client network, enabled the use of peripherals.
- Wireless access over the Thin Client network was possible: seven of the schools studied reported using laptops in Thin Client mode over a wireless network.
- Reliability: Thin Client terminals were reported to be very reliable, and easy to replace when they failed. Five schools reported 99 per cent uptime on the server, which helped ensure a very consistent resource for teachers throughout the school calendar.
- Security: six schools reported that Thin Client technology had reduced the risk of viruses attacking terminals or servers. Patches, updates, virus signatures and other security measures can be applied to the whole network at once, helping to increase security and make the network less prone to attack. Schools also found that having Thin Client network reduced the chance of pupils tampering with the desktop and changing the configuration.

- Reduced energy and heat: those interviewed in two schools also reported that Thin Clients are a 'greener' alternative, because the terminals use less power and produce less heat than the equivalent number of Fat Client computers.

1.3.2 Issues

- Functionality: when examining schools against Becta's Functional Specification for Institutional Infrastructure, the schools studied had to use their Fat Client network to augment the functionality of the Thin Client network in order to meet some elements of the specification – for example: 'all educators and learners should have access to a wide range of applications that allow the manipulation of text, images (including video), tables and sounds' (see section 5.3).

1.4 Technical support

All four primary schools used service providers for technical support, with half of these schools also having some form of in-house support for more routine problems and maintenance. Of the eight secondary schools, only two used any form of external provision for technical support. The remaining schools preferred to use in-house technicians to provide the support they required. Some of these schools retained services from a third party for patching and server software upgrades, which can be done remotely.

Those interviewed were not able to give the lifespan of their Thin Client terminals, so no comparison has been made here on this.

1.4.1 Benefits

- Central management and support: all schools upgraded or installed new software (which ran on the Thin Client network) and fixed problems centrally, making technical support easier. (Central distribution of software can be achieved on Fat Client networks, though most systems download new software on being switched on. This can cause a delay in starting lessons if the machines have not been booted up beforehand. In addition, there can be greater management overheads: Fat Clients typically need more individual support as they have local operating systems, applications, drivers and a variety of builds depending on variations in physical hardware.)
- Reduced time for technical support: several schools reported that the time spent supporting the Thin Client network was less per terminal than the Fat Client network. For example, School 5 reported that initially the school spend a lot of time refining the Thin Client installation, but had spent almost no time supporting the Thin Client devices in classrooms.

1.4.2 Issues

- Secondary schools generally did not cut back on staffing for administrative support, mainly because they retained some Fat Client estate. They were, however, able to support a larger number of terminals within the same spend on staff.

1.5 Total Cost of Ownership

From the qualitative school visits and the data returns provided for the first phase of the research, it was clear that there was a perception amongst those interviewed that the installation of a Thin Client network reduced overall costs. The data supports this conclusion for secondary schools, but not for primary schools in this study.

The data indicates that the Total Cost of Ownership for Thin Client networks in secondary schools is less than the Fat Client counterparts studied in this report. The opposite is true for primary schools.

The Total ICT costs per staff member (excluding the hardware element) are very similar for both Thin and Fat client primary schools and marginally lower for Thin Client secondary schools than Fat Client secondary schools. However, once hardware is included, Thin Client is more expensive than Fat Client per staff member in the primary schools, but less expensive in the secondary schools studied.

1.6 Lessons learned

Each of the schools interviewed was asked to provide advice for other schools considering Thin Client technology. They offered the following key points:

- **Visit other schools:** before implementing a Thin Client network, talk to someone who has already implemented a Thin Client network in their school and arrange a visit. Talk to them about their experiences and use this to help shape your own objectives and approach.
- **Define clear objectives for what you want:** many of the schools in our study said they had a clear single objective to resolve the requirement to expand access to ICT whilst keeping costs to a minimum.
- **Ensure you have appropriate experience on your team:** for some schools, this may mean in-house expertise whilst others may rely on external expertise. Decision-makers in the school need robust advice, and should consider carefully how best to secure that. In addition, schools should consider whether technical support is to be delivered in-house, by an external provider or by a mix of the two. Whichever solution, it is important to make sure that you have the level of support you need to ensure that the network works well and is properly maintained to prevent future problems arising.
- **Have a structured design process:** decide what outcomes you want and get the people with the appropriate expertise to design your system.
- **Don't underestimate the capacity of the servers required**: where schools ran into difficulty with their implementations, it was usually because the servers were underspecified (in some cases old computers). Those who did not have these difficulties had procured servers with sufficient capability not only for current needs but also future expansion.
- **Consider your educational software requirements**: not all software is designed to work on Thin Client technology. Check with your intended network provider about the applications and curriculum software you wish to run on it. Ask them to organise a demonstration for you, so that you can check for yourself that they work. Ensure that they can work under multi-user scenarios. One school in our study advised others to remain focused on the types of software to be used: they thought it was better to have fewer applications that work well on Thin Client and as proficiency increases, to move on.
- **Consider the skills of your teachers and pupils**: consult them. If you are opting for Open Source Software, your staff and pupils may need some training to learn how to use the new software. Becta has provided an independent report on Open Source Software. It is available online.

  [http://www.becta.org.uk/corporate/publications/documents/BEC5606_Full_report18.pdf]

- **Be aware of the Total Cost of Ownership:** the case studies suggest that the total cost of ownership in primary schools may be greater for Thin Client than for Fat Client systems. The opposite is true of secondary schools in this study. This may be because the greater size of the secondary school networks enables economies of scale to be introduced.

Finally, schools may wish to consider their view of future developments in Thin Client technology. Undoubtedly, server and network technology will improve, but will this mean that all multimedia applications will work on Thin Client technology in the future? The schools interviewed for this report were divided on this issue; one school is currently migrating from a Thin Client network to a predominantly Fat Client environment to be able to accommodate multimedia in all aspects of teaching.

2 Introduction

Most schools now have extensive information and communications 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 per cent of primary schools in that survey were implementing a Thin Client network and 9.2 per cent of secondary schools). There has been no comprehensive study of the capabilities and appropriateness of such systems in education.

This research is divided into two reports, of which this is the second:

- Report 1: a review of the research literature and existing projects relating to the use of Thin Client technology in schools
- Report 2 (this publication): 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
- allow schools to make informed decisions both directly through published reports and indirectly through Becta's advice to schools.

The case study data for this second report was collected through the following methods:

- A questionnaire sent to the school for the first study collecting numerical evidence of their ICT resources, the types of terminals on the Thin Client network, the functionality of the network etc.
- Two visits to the school, interviewing key personnel. The first day-long visit involved interviewing the headteacher, ICT co-ordinator, a class teacher and an administrator or class assistant. Further interviews or discussions took place with groups of teachers in some schools. The second visit, which focused on the technical aspects of the study, involved an extensive interview with the leading technical person in the school such as the ICT co-ordinator or e-learning manager.
- The school also gathered together financial and technical data, which was entered on an online tool, to help the researchers analyse the Total Cost of Ownership. Further information on this is given in section 13 on methodology.

2.1 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 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 hard disks 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 usually 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 (in this report) 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 central 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. No schools in this study used this technology.

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.

It is worth noting that Thin Client technology, as with other ICT, is continually improving. Schools in this study with newer terminals and servers had better multimedia performance and better support for peripherals. Manufacturers continue to work to improve the capabilities of machines and protocols.

In addition to this the emergence of application streaming is also offering some promise of resolution of resource-intensive applications in a centralised model. This technology effectively stores an application centrally and streams it to a 'virtual machine' which is set up on the target terminal. It does not interact with the terminal's operating system and can continue to be managed and locked down centrally. It can, however, use local processing and memory resources which are dedicated to the processes demanded by a single user, and handles all screen updates local to the machine, reducing the overhead on the network.

It is also important to bear in mind that the 12 Thin Client schools studied all had different networks in place. What applies to one network does not necessarily apply to others. For example, some networks and terminals were able to support some USB peripherals whilst others were not. Functionality and performance varied across the schools studied.

3 Overview of the case study schools

3.1 Nature of the Thin Client network

Table 3.1 summarises what the 12 schools have implemented. All schools implemented some form of hybrid solution, using a Fat Client network in places and Thin Client network in others. The main reason given by the schools for this was that they wanted to retain the useful ICT resources they already had. None of the 12 schools were starting from a position of no ICT resources. Furthermore, unlike many businesses and industries, educational needs across the school are not uniform. Therefore it is not surprising that one 'solution' across the school would not be the best approach to upgrading their ICT resources.

The purpose of the Thin Client network varied from enabling remote access at home, through to use across the teaching and learning areas in the school. As explained in the executive summary, all 12 schools wanted to enhance and enlarge their existing ICT resource rather than replace it totally.

From this, some common themes are clear. All schools in the study operate some form of hybrid network, and ten of the 12 used Fat Client for their school administration.

There are also some large differences: the number of thin client terminals per server ranged from 10 to 85 and the percentage of bespoke Thin Client terminals as part of the whole estate ranged from 0 to 71 per cent. This shows that schools have not adopted identical solutions; rather, as the later analysis shows, they have studied their needs and decided how best to meet them. This has resulted in some similarities and some differences, which will be examined in more detail in this report.

Table 3.1: Summary of Thin Client network in the twelve case study schools

	School 1 (Primary)	School 2 (Primary)	School 3 (Primary)	School 4 (Primary)	School 5 (Secondary)	School 6 (Secondary)	School 7 (Secondary)	School 8 (Secondary)	School 9 (Secondary)	School 10 (Secondary)	School 11 (Secondary)	School 12 (Secondary)
Size of school	380 pupils, 16 teachers	270 pupils, 14 teachers	335 pupils; 14 teachers	360 pupils; 15 teachers	970 pupils; 94 teachers	1444 pupils; 106 teachers	1408 pupils, 90 teachers	950 pupils, 55 teachers	1043 pupils; 86 teachers	740 pupils; 50 teachers	2000 pupils; 120 teachers	1400 pupils; 103 teachers
Thin Client Terminals												
Bespoke Thin Client	35	27	31	30	56	0	80	120	30	122	0	490
Legacy computers used as Thin Clients	2	3	0	38	39	10	0	0	105	8	200	50
Other desktops and laptops used as Thin Clients	0	50	0	17	0	0	200	0	0	78	100	0
Total number of Thin Client terminals	37	80	31	85	95	10	280	120	135	208	300	540
Total number of Fat Client terminals	17	58 (50 of which are also counted in Other above as dual boot machines)	37	26 (of which 14 are dual boot lap tops included in “other above”	261	655	100 laptops and the 200 desktops above, which can also operated as Thin Clients	115	289	not known	not known	374

	School 1 (Primary)	School 2 (Primary)	School 3 (Primary)	School 4 (Primary)	School 5 (Secondary)	School 6 (Secondary)	School 7 (Secondary)	School 8 (Secondary)	School 9 (Secondary)	School 10 (Secondary)	School 11 (Secondary)	School 12 (Secondary)
Network details												
Age of Thin Client network	8 years	4 years	7 years	3 years	1 year	2 years	7 Years	3 years	3 years	9 years	5 years:	2 years
Number of servers	2	4	3	1	2	1	7	8	12	13	6	12
Network specification	100Mbps LAN	100Mbps LAN	100Mbps LAN	100Mbps LAN	100Mbps LAN	100Mbps LAN	100Mbps LAN	100Mbps LAN	100Mbps LAN	100Mbps LAN	100Mbps LAN	100Mbps LAN
Hybrid or pure Thin Client	Hybrid	Hybrid	Hybrid	Hybrid	Hybrid	Hybrid	Hybrid	Hybrid	Hybrid	Hybrid	Hybrid	Hybrid
Solution for school administration	Fat Client	Fat Client	Fat Client	Fat Client	Fat Client	Fat Client	Fat Client	Fat Client	Fat Client	Fat Client	Hybrid, but predominantly Thin Client	Thin Client
Average number of Thin Client terminals per server	19	20	10	85	48	10	40	15	11	16	50	58
Operating system	Windows 2003 / RISC OS & Citrix	Windows 2003	Windows Server 2003Enterprise Edition	Windows Server 2003 Enterprise Edition	Windows Server 2003 Enterprise Edition	Windows Server 2003 migrating to Solaris 10 and Tarantella	Windows 2003 and Citrix	Red Hat Linux with Linux Terminal Services	Windows 2000 and Citrix	Windows Server 2000 and Citrix	Windows 2003 and Citrix, with Linux on the desk top for Thin Clients	Windows Server 2003 Enterprise Edition

Three primary schools studied (Schools 1, 2 and 4) had no network in place prior to implementing their Thin Client network. This is significant, since it means that some of the benefits experienced by the schools may be the result of having a network for the first time (or a working network) and not necessarily a Thin Client one. It also limits the possibility of making direct 'before and after' Fat Client versus Thin Client comparisons, though those interviewed may of course have had experience in other schools.

3.2 Advantages and disadvantages of different types of implementation

Three different types of Thin Client systems were observed in the case studies which are broadly as follows.

- MS Terminal Services: this was used where an all-Microsoft Windows environment was required. There were no discernible differences in the reported performance or capabilities of this system and other third-party Thin Client solutions.
- Citrix: this was used to deliver a number of operating system environments, including Unix, Windows and RISC OS. Where Citrix has been deployed the decision was taken for one of three reasons:
  - At the time of the implementation, Citrix was the only mature solution available (some of the networks studied are approaching eight years of age)
  - In two cases there was a requirement to deliver ongoing support for legacy non-Windows applications and Citrix had a wider capability to deliver these
  - Citrix was the mechanism chosen by the network provider.
- Linux Terminal Services: there was one instance of a school using Linux Terminal Services. This school had selected this purely on a basis of cost. This change from more familiar Windows environment and associated applications was seen by those interviewed as a key detracting factor to acceptance of the network, although the stability and security of the network was similar to the other options.

In the majority of instances the Thin Client network was co-hosted on the same servers that provided the file and print environment, authentication services and Fat Client support. These deployments were a mix of single server deployments (typically in primary schools), multiple servers with basic round robin session load balancing, and multi-server environments with sophisticated load balancing based on dynamic resource conditions (which means that the decision on which server hosts a particular session is based on which has the most spare processing and memory power, not a round robin distribution). The size and complexity of the environment, coupled with the technical skills within the school correlated to the adoption of complex load balancing solutions. The performance of systems was not measured at any of the schools so it is not possible to tell what impact this has had.

One exception was School 7, which had created a Citrix farm to host the client applications on a high-performance set of computers used as a front end, with a lower specification Windows Server environment delivering file and print services and supporting the Fat Client network. By divorcing the two platforms, the Fat Client network was not affected by the load placed on the system resources by the Thin Client network. This aided performance, but was costly.

4 Reasons for implementation

4.1 Reasons for choosing Thin Client technology

Among the 12 case study schools, there was overwhelming agreement on the three main drivers for deciding to implement a Thin Client network, which are inter-related:

- Cost: 11 of the 12 schools studied cited cost as a primary driver, wishing to increase the number of terminals for the budget that the school had available. However, School 6 was gradually moving away from Thin Client to Fat Client machines for curriculum support because it was possible to buy Fat Clients almost as cheaply as Thin Client terminals.
- Increased access: all schools wished to increase access to ICT by expanding the network of terminals within their building.
- Complementing existing resources: most schools wanted a system which would add to their existing resources, cause minimal disruption and not increase the management and operational costs significantly.

Only one school (School 2), a primary school, did not mention cost as a key driver. This school wanted to extend access, but its main concern was to provide an environment that was consistent and reliable, giving teachers the confidence to use ICT in lessons, as previously the technology had been perceived as a barrier. They had assumed that a Fat Client network would be used, but on exploring the benefits of Thin Client technology, decided that this best suited their needs. Those interviewed in the school reported that a Thin Client system provided the consistency the school was seeking. Even though teaching and learning was the main driver, the school's head of ICT also recognised that the low cost of terminals relative to Fat Client networks had enabled wider access.

These and other reasons schools mentioned for going down the Thin Client route are set out in the table below, together with a brief commentary on whether the reason or benefit was realised.

Reasons given for implementing a Thin Client Network	**Whether schools realised this benefit**
Increasing access whilst containing costs	Costings or tenders illustrated that it would be cheaper per terminal to adopt the Thin Client network. The 12 schools studied have been able to purchase either low-cost terminals, or in many cases recycle low-spec PCs that they already had, to expand the networks as a result of the deployment of Thin Client technology. However, the Total Cost of Ownership element of this study suggests that only secondary schools were able to achieve economies of scale when implementing a Thin Client network, whilst primary schools have a higher Total Cost of Ownership per terminal when implementing a Thin Client network.

Reasons given for implementing a Thin Client Network	Whether schools realised this benefit
Easier to support	Seven schools noted that the Fat Client network took more staff time to support per terminal. Thin Client technology enabled schools to realise benefits of centralised network management, administration and support. For example, the network manager in School 1 was teaching at the time the network was being replaced and did not have enough time to manage individual computers and to teach a class. There was not enough in the budget to employ a technician, and so a Thin Client network was implemented, which enables administration to be done remotely by a support company. (This could also be done on an appropriately configured Fat Client network, though individual computers would still need more attention in comparison to Thin Client terminals).
Reduced cost of maintenance	Schools reported that the Thin Client terminals required less maintenance because of the absence of moving parts and software being managed completely on central servers. For these reasons, they found the network easier and much cheaper to maintain in terms of staff time.
Greater reliability	Those that used higher specification server technology reported a high degree of reliability. Schools making use of legacy computers as servers ran into some difficulties and subsequently had to upgrade their servers. Reliability of Thin Client terminals was reported to be better than Fat Client computers. For example, according to the ICT co-ordinator of the primary School 3, the Thin Client network 'runs so well and is so reliable that there is a lot less work to do. Beforehand it was impossible to keep control of the ICT resources'.
Ability to make use of legacy equipment	Over half the schools used at least some legacy computers. This enabled schools to establish the Thin Client network with the required number of terminals for a lower cost than if purchasing bespoke Thin Client terminals only. Most legacy computers also have USB and serial ports, enabling the use of peripherals (though this is becoming less of an issue as more recent Thin Client terminals have USB ports).

Reasons given for implementing a Thin Client Network	Whether schools realised this benefit
Lower consumption of energy	Two schools (1 and 12) reported that Thin Client was a 'greener' alternative, because terminals use less power and produce less heat than the equivalent number of Fat Client computers.

4.2 Influences on decisions

Only School 5 cited their Local Authority as providing a source of advice on benefits and issues to do with implementing a Thin Client network, though according to the school the Local Authority did not have much expertise in Thin Client technology. The Local Authority for School 1 was not able to provide advice to the school at the time, but has kept in close touch with the school to learn from its experience, with a view to providing advice to other schools. School 6 mentioned Becta as a source of advice: 'The school likes to keep up with Becta's recommendations' (e-college manager). This echoes the findings in the first report on Thin Client technology, where local authorities were generally found not to have a policy on Thin Client technology or to provide support and advice on procuring it. Schools wishing to consider this technology therefore have to find alternative sources of advice and guidance.

By far the most significant influencers of the 12 schools studied were the private sector providers of Thin Client technology. All 12 schools took the initiative to review and redefine their ICT requirements and to research how these might be met rather than follow a policy provided by the Local Authority. Eight of the schools said these network providers had provided a demonstration of Thin Client technology and its benefits, and this had persuaded them to consider the option more carefully.

Some schools also sought additional advice:

- One school (School 11) had employed an external consultant who came to the conclusion that Thin Client technology was the best way to rapidly expand ICT provision whilst minimising the cost.
- Three schools had visited other schools implementing Thin Client technology. Though this is only one quarter of the case study cohort, many schools recommended visiting another school as a key step to take before deciding to implement this technology.
- One school (School 12) mentioned that the headteacher had been on the Strategic Leadership in ICT (SLICT) course, run by the National College for School Leadership and supported by Becta.

One school (School 8) decided to implement a Thin Client network on their own, without seeking any external advice.

4.3 Procurement processes

Schools went through a variety of processes to decide on Thin Client technology as their network, and then which company they should use to provide the equipment and which company to support it. The case studies did not explore the decision-making process in detail, partly because in some cases the people that had been involved in the original decision-making process had moved elsewhere.

Six schools undertook a comparison of different networks or suppliers before concluding which network to implement. However, one surprising finding is that of the schools that used external companies to provide a network (as opposed to building the network themselves), three did not undertake a competitive tendering exercise. One received a demonstration and, as they were not aware of any competitors in the educational market, went with that company. Another used a company to run structured comparisons of different networks and then used the same company to implement their preferred network.

Whilst the failure to use competitive tendering is not to be encouraged, the case studies for these schools (Schools 1, 3 and 5) show that the implementation was successful, and the schools involved were confident they had gained value for money.

The key differentiator in terms of schools' experience was who built the network: a private sector company or the schools themselves. Three schools decided to build the network themselves (Schools 7, 8 and 11). Two of these schools used legacy machines as Thin Client servers and these did not have the capacity to handle large volumes of network traffic. Consequently the users' experience suffered until these machines were replaced.

5 Technical benefits and issues

5.1 Type of networks in place

All of the schools studied used some form of hybrid system, making use of Thin and Fat Client networks and stand-alone machines (including laptops) to deliver the diverse needs of teachers, learners and administrators. All of the schools visited used a single LAN connection to both the Thin and Fat Client terminals. Systems used for administration were connected via the same network infrastructure but in some cases had not been enabled with server mappings and were separated on a different logical virtual LAN. It was also the case that the underlying server(s) which provided applications and file storage were shared between the networks, meaning that both Thin Clients and Fat Clients could access the same folder structures and therefore efficiently share data between the two. There were two main reasons for this:

- The Thin Client network had difficulty delivering multimedia applications due to performance constraints. Eleven schools retained a Fat Client network to enable staff and pupils, particularly those in music and design and technology, to take advantage of multimedia applications.
- In 10 of the 12 schools the management information system (MIS) was run on a Fat Client network, either because this was stipulated by the Local Authority because of compatibility problems between the school's MIS and the Thin Client network software, or because the MIS software provider does not support the software when it is run on a Thin Client network. However, three schools had no problem using their administrative system over the Thin Client network and one other school used a mixed economy of Fat Clients for Local Authority requirements and Thin Clients for its own administration.

The balance between the two types of networks varied considerably. For example, one secondary school had 75 per cent of its terminals working as Thin Client terminals (excluding laptops) whilst another secondary school had over 400 computers only ten of which are dedicated Thin Client terminals.

5.2 Servers

Schools typically bought the best servers they could afford, or whatever was specified by their supplier. The researchers' visits did not uncover any process of defining a required performance and applying this to the selection of the number of servers or their specification, in spite of the fact that the server(s) would determine the performance of the network. Some schools found that once implementation had taken place, they needed higher specification servers (Thin Client networks typically need higher specification servers to cope with the greater demand placed on them). Even where schools undertook server upgrades, this was not found to be particularly structured.

The following table shows that primary and secondary Thin Client schools had roughly the same number of terminals per server – roughly half that of the average Fat Client school studied.

Table 5.1: Ratio of terminals or computers per server in Thin and Fat Client schools studied

	Thin Client Low	Thin Client High	Thin Client Average	Fat Client Low	Fat Client High	Fat Client Average
Number of personal computers / terminals per server in primary schools	22.0	45.5	30.5	8.8	121.0	53.9
Number of personal computers / terminals per server in secondary schools	13.8	55.3	29.8	26.0	99.4	62.7

5.3 Functionality

Becta's *Functional Specification; Institutional Infrastructure, version A* (Becta, 2005a) sets out a number of requirements that schools should aim to ensure are met by their ICT network. The following observations are made against selected elements of that specification:

- ***All educators and learners shall have access to a wide range of applications that allow manipulation of text, images (including video), tables and sounds*** *(ref. 1.2.1 in Functional Specification)*

  Manipulation of text and tables was not found by schools to be problematic on the Thin Client network. However, multimedia images and sounds did cause some problems. Eleven schools had retained a Fat Client network to deliver such software. Some schools also worked around this limitation by setting a cap on the number of pupils accessing the multimedia package at any one time, to avoid overburdening the network.

  This evidence shows that schools are able to find ways of working around the limitations of their Thin Client network, either by not using demanding multimedia or by restricting access to it. Further research would be needed to explore whether those schools that taught in ways that did not require multimedia software were limiting their pupils' ability to follow the National Curriculum in any way, and whether the style of teaching was any more or less effective compared to those schools using the full range of multimedia ICT.

  The schools studied had to use their Fat Client network alongside their Thin Client network to meet this criterion. However, further research would be needed to determine whether there are Thin Client solutions available that can meet this requirement in full.

- ***Learners and educators shall have access to a wide range of access devices*** *(ref. 1.2.4 in Functional Specification)*

  Access to desktop computers (terminals in the case of the Thin Client network) and laptops was generally possible on the Thin Client network, but only one school reported using PDAs on the Thin Client network, and this was on a trial basis.

  Nine schools in this study reported using laptops effectively on the Thin Client network. Some, as described above, operated over wireless technology as mobile Thin Client terminals. Others, particularly teacher laptops, were dual boot, enabling the teacher to use the laptop in stand-alone mode as a Fat Client, or over the Thin Client network when they were able to connect to the network. This aided flexibility, as teachers could use ICT where and when they wanted to.

  The schools studied show that this criterion can be met with Thin Client technology.

- ***Learners and educators should have access to a range of collaborative tools*** *(ref. 1.2.7 in Functional Specification)*

  Email and internet access is provided on Thin Client networks, giving access to online communities, blogging and wikis. Document sharing is possible, via shared folders on the network, but voice and video conferencing is generally provided on separate traditional circuit switched networks (such as PSTN and ISDN) networks, so not on Thin Client.

  With the exception of video conferencing and voice, the schools studied show that this criterion can be met through Thin Client technology.

- ***Learners and educators shall be able to access appropriate curriculum resources and administration data from all computers in the institution and from all learning spaces within the institution*** *(ref. 2.2.2 in Functional Specification)*

  As has already been mentioned, all schools reported having difficulties running multimedia applications that require video and sound over the Thin Client network. The researchers also came across examples of specific educational applications not working on the Thin Client network.

  On the positive side, a wide range of educational titles can be run on some Thin Client networks. One school reported running a test of the educational titles they wanted to use before deciding to implement the Thin Client network and found that the vast majority of the titles did work.

  Three schools (Schools 7, 8 and 11) reported using Open Source software on their Thin Client networks. One of these schools reported that there was an issue in finding software that would run on the Open Source platform (Linux). The school had, however, adopted a Windows emulator package for Linux which enabled them to run a number of Windows applications via this system on the Thin Client network. School 1 had started off using Open Source, but this had proved unpopular with both staff and pupils, so the school had abandoned using it, in preference for a Microsoft Terminal Services based

network. The reasons for doing so are related to Open Source software, and not Thin Client, so we have not explored this issue further.

Ten schools maintained separate administrative networks using Fat Client technology. This means that not all computers on the network are able to provide appropriate access to administration data. The schools studied had to use their Fat Client network alongside their Thin Client network to meet this criterion.

- ***Institutions shall provide secure access to curriculum and administration data from remote locations*** *(ref.2.2.3 in Functional Specification)*

  Remote access solutions varied, but the schools studied show that it is possible to meet this criterion using a Thin Client network.

  Where schools used laptops, data was synchronised with or placed on the server in a number of ways. In some cases teachers accessed the school network remotely using Thin Client sessions and therefore worked on the documents on the file server as if they were in school. In other cases work was undertaken completely remotely (on a home PC, for example) and transferred to portable storage devices and then copied to the school file server via a Fat Client terminal initiated on the school network. The third method was for files to be created off of the school network and emailed to a school email account. These could then be saved to the file server either from a Thin Client session with Thin Client presented email client or via a Fat Client session with traditional mail client.

- ***Institutions shall ensure that educators and learners have access to a wide range of supportive tools*** *(ref. 2.2.4 in Functional Specification)*

  All of the schools that reported using interactive whiteboards did so either over a Fat Client network or connected to a stand-alone laptop.

  Five schools did not support any peripherals on the Thin Client network. Seven schools are able to support a range of peripherals over their Thin Client network, partly because modern terminals are able to support many USB devices and partly because legacy machines have been used and this functionality has been retained.

  With the exception of interactive whiteboards, the case studies show that this criterion can be met using a Thin Client network, though many schools chose to use a Fat Client network to provide the full range of functionality, including multimedia software and peripherals.

- ***Institutions should provide secure wireless access to the curriculum and administration resources from a range of work spaces in the institution*** *(ref. 2.2.7 in Functional Specification)*

  Seven of the schools studied reported using laptops in Thin Client mode over a wireless network. One other school intended to implement a wireless network, and the others had not put one in place, and there was no indication that they had explored this option.

  School 11 found that the performance of the Thin Clients is consistently good over wireless technology for standard productivity tools and simple curriculum

applications. When using these types of applications, each client placed a relatively consistent load on the network. The schools found that Fat Clients perform well whilst processing information locally, but when it is necessary to bring data across the network to process it, the limited bandwidth of the wireless network makes this less than optimal. The Fat Client performance is therefore more variable when using the wireless network for standard productivity tools and simple curriculum applications. This is because if the 30 Fat Clients at the start of the lesson all attempt to download a large file (say a presentation of 1MB) then there would be a significant burden placed on the network at that point, and also at the point when work was being saved to the file server. This affects lesson continuity at the points in time when the data is accessed. Fat Clients were therefore perceived by the schools to have performance issues when downloading or uploading data using standard productivity tools and simple curriculum applications, although the network is unused for the majority of the lesson. Thin Clients, which use the network continually, were not perceived to have performance issues for standard productivity tools and simple curriculum applications because this continued usage is well within the overall capacity of the network provided.

This research suggests that appropriately specified wireless technology does work effectively using Thin Client networks.

Ten schools maintained separate administrative networks using Fat Client technology. This means that not all computers on the network are able to provide appropriate access to administration data. The schools studied had to use their Fat Client network alongside their Thin Client network to meet this criterion.

- ***An institution shall make secure all access to data held on the network and shall control access to that data*** *(ref. 4.2.6 in Functional Specification)*

  A key feature of Thin Client networking is that the data always remains within a central secure environment. Schools did not report any difficulty making data secure on the Thin Client network. The ability to tightly control access to and use of, the network undoubtedly helped. Security is aided with data being stored centrally on the server by default, with appropriate access controls reducing the risk of unauthorised access. The centralisation of data enabled the schools to implement a structured approach to backing up data, and the storage and back-up systems range from file server and single tape back-up to sophisticated storage area networks and automated tape libraries for high-volume archiving. The size of the environment and the availability of internal skills is a key driver in defining the requirement and the approach. None of the schools had any current issues with the integrity of existing data.

  The case studies show that this criterion can be met using Thin Client technology.

5.4 Multimedia

'Multimedia' is used to describe a variety of applications and content. At their simplest, these include documents and presentations with large and complex graphics. They may also include small-scale animations such as clip-art or the animation of slide builds in PowerPoint. These low-level multimedia applications were found to be able to run on Thin Client systems. However, the increasing complexity or numbers of users will affect performance.

At a higher level is a group of educational applications that include some animations or streaming audio elements. Examples of these may be a science program showing the Earth's rotation and phases of the moon, or language programs that include an audio response or prompt. The visual applications were found to run in small volumes but had a higher impact on the network as well as the servers than the previous category. These typically experienced screen freeze and lack of smooth presentation but may still be effective in demonstrating a principle. Audio streaming, however, was fatally degraded where the network or servers could not support an optimum delivery.

At the highest level of applications are large-volume video and audio streaming with high resolutions and quality output. This incorporates video and audio editing which often requires repeated play, review, and frame advance techniques which will quickly saturate a network in Thin Client mode, even where the servers have the processing and memory capability to accommodate the usage.

All schools reported problems using multimedia content. Schools with newer Thin Client terminals experienced better multimedia performance, but still used Fat Clients for more powerful multimedia applications. In School 12, the teachers found it hard to understand why, with such an extensive network in place, multimedia programs could not be run on all machines. Schools had different solutions to this problem. For example:

- School 2 limits the number of pupils using the multimedia applications at any one time
- School 3 turned off much of the functionality of multimedia software packages so that the software 'behaved better'
- School 5 found that the Thin Client network is capable of running some rich multimedia applications (perhaps because the servers and terminals are only one year old and therefore newer and of a high specification), but it was not able to support all those being used by the school. For example, video from one private-sector source runs too slowly on Thin Client terminals, whereas multimedia science programs run satisfactorily. The school uses Fat Client computers to run the applications that won't work satisfactorily on Thin Client terminals, although these are not widely used within the school;
- School 7 found that upgrading to higher specification servers and network capacity had largely made multimedia accessible from Thin Clients. However, whilst they found that multimedia applications can be run on the Thin Client system, the potential to impair the performance of the whole system is such that this is not allowed. All CAD, photo and video-editing applications are run on Fat Client systems. There are some animations that will run on the Thin Client network, but there were many instances of poor performance when doing so, so the teachers did not generally try. In modern languages, the same was true of audio streaming, where software would work but the performance degraded with large numbers of users. Some departments do not favour Thin Client terminals because of multimedia limitations. For example, the music department uses Apple Macs and the MFL department uses PCs.

- School 8 used Apple Macs in the music department because of the range of software used and the sophistication of the graphics in programs. The design and technology department used PCs as some of their software is not compatible with the Thin Client system adopted.
- School 11 does not deploy multimedia applications on the Thin Client network as they do not run efficiently and affect the performance of the rest of the network. This school views the incorporation of multimedia as fundamental to the teaching of ICT and other subjects and as a result, has undertaken all recent expansion within the Fat Client environment. The school is currently migrating to a predominantly Fat Client environment to be able to accommodate multimedia in all aspects of teaching, and as a result of very little requirement to teach standard office-type features. This change in demand is a reflection of the penetration of and familiarity with ICT amongst students before attending the school.

Other schools limited the number of pupils able to use the multimedia content at any one time. For example, School 2 adopted this approach, combined with having some Fat Client computers to improve flexibility. Teachers in these schools had to adopt pedagogies that involved group work, to enable rotation of pupils so that all could work on the media-rich content.

5.5 Network performance

Four schools reported that they had no network performance issues, but Schools 3, 4, 5, 10 and 12 (40 per cent of those studied) reported that the Thin Client network slowed down significantly when a large number of users were accessing it at the same time (In school 5's case, this only applied to internet access and was because of the bandwidth available for that function.) What needs to be noted here is that each school had a different Thin Client network and configuration, with some having more up-to-date technology which enabled them to run more powerful software than others. Furthermore, there was no evidence obtained about the frequency and extent of concurrent use of terminals. Some reported that the networks were slowest at the start of lessons when everyone could be logging on at the same time. Other schools reported that the network was slowest during break-times when possibly pupils were trying to use more extensive software or download large picture and video files.

There are a variety of reasons for slow performance on Thin Client networks. Bandwidth can be a reason, but this was not cited by those interviewed in the schools observed. Rather, those interviewed thought it was due to the demand that system resources place on the servers. Because all of the processing takes place on the server, each user takes some of the memory and processing power. Some applications (such as multimedia applications) are also more processor and memory intensive. It is not possible to clarify the limits to how many users can be on the network at the same time before performance starts to deteriorate, as that depends on the specification of the server running the applications and what applications are being run. Fat Clients on the same network are generally not a problem as network bandwidth is not the issue (except in wireless areas). The Fat Clients may place a temporary load on servers at log-on and when downloading files, but then all of the processing is local to the Fat Client and has no impact on the Thin Client server.

Further work would need to be done to measure the detailed uses of all machines across schools over a period of several weeks to be able to explore the extent to which this performance issue affects teaching and learning. It should be noted that the schools

concerned still reported a positive impact on teaching and learning due to greater access to ICT and greater reliability of the Thin Client network.

5.6 Use of legacy computers

As defined above, legacy PCs are older PCs that have become obsolete due to their specification being insufficient to be able to run modern Fat Client software and / or hardware. Because Thin Clients require less local processing power and memory, legacy PCs can often be redeployed in a Thin Client environment to extend their life. This extends the upgrade cycle, allowing the school to reduce spend on setting up the Thin Client network and replacing old terminals. Also, when upgrading the network, legacy PCs can continue to be used whereas Fat Client networks might well require upgrades for older specification machines.

All schools had made use of legacy computers on the Thin Client network, ranging from School 1 with only 2 legacy computers used, through to Schools 11 and 12 with 200 legacy computers each on the Thin Client network.

Many had used legacy computers to reduce the cost of establishing the network. However, another key reason was that the legacy machines had USB ports and serial ports which, if enabled on the Thin Client network, allowed the use of peripherals (see below). This increased the functionality of the Thin Client network, which was seen as an advantage. Other schools (for example, School 9) reported recycling legacy laptops from teachers as portable Thin Clients that are retained in a central bank and can be deployed on an ad hoc basis to deliver an extensive ICT environment for the teaching of specific lessons (all laptop access in this school is wireless). This increased the flexibility and overall provision that the school was able to offer.

This same school also reported that recycled computers are less reliable as a result of their age and the existence of 'moving parts' that are not present in bespoke terminals. They found that laptops deployed as Thin Clients were particularly problematic as they are less robust and therefore prone to accidental damage in lessons (a limitation which is true of laptops in general, not just those being used as Thin Clients).

5.7 Reliability of terminals and network

Apart from the use of recycled, legacy computers, schools reported the Thin Client terminals to be very reliable. Where machines did go wrong, schools reported that they were easy to replace as terminals can be swapped easily and require little configuration. In addition, as reported in at least two schools, schools can and did have a small supply of terminals in reserve at much less cost than keeping the same number of Fat Client PCs.

Any problems with the software can be rectified centrally across all machines at once. In addition, the need for such fixes is reduced because central installation and upgrades of software mean that problems due to incorrect installation or not having the latest software are reduced.

Ten schools reported greater reliability of the Thin Client network and terminals. Five of these reported 99 per cent uptime on the server, which helped ensure a very consistent resource for teachers. This increased reliability is one of the key benefits of Thin Client technology, and schools reported that it had helped teachers, particularly those who were

previously concerned about the reliability of the technology, to increase their confidence and make more use of ICT in their lessons.

Of the two schools that did not report greater reliability, one said there was no difference between the Thin Client network and the Fat Client network because the Fat Client network was reliable. School 12 reported two days per term downtime on the Thin Client network, (largely due to teething problems), and added that disaster recovery was very rapid because of the robust server system and because the supplier provided a very rapid response.

School 9 had experienced significant issues logging into the network using Fat Client computers. This was caused by 30 children logging on to the system and opening files simultaneously. This had two effects. The first was a high demand on the authentication services and the second a demand on the network to move files from the file server to the Fat Client. Whilst the new Thin Client network has resolved these issues, the school recognised that an upgrade to the network and existing Fat Client hardware would equally have improved the performance.

School 8 reported that a key factor relating to the administration of Fat Clients is instability of the image. Prior to deployment of the Thin Client network students were able to exploit vulnerabilities in the system and create instability by deploying unauthorised software or disrupting the integrity of data.

5.8 Security

Schools reported greater physical security of their network, due to the inability to use Thin Client terminals off the school network, so deterring thieves. One school had notified the community of their solution, spreading the word that the terminals would not work unless on the network. Inner-city School 5, which had experienced some thefts of ICT equipment previously, had bolted their Thin Client terminals under the work benches out of view of possible thieves.

In addition to physical security, the Thin Client networks were also reported as less prone to the following security issues:

- Viruses and malware: six schools reported that Thin Client technology had reduced the risk of viruses attacking terminals or servers. The Thin Client network reduced the chance of pupils or teachers introducing malware via external media where peripheral data storage devices are not supported. Patches, updates, virus signatures and other security measures can be applied to the whole network at once, helping to increase security and make the network less prone to attack. Schools reported that this reliability helped them reduce the amount of support required for the Thin Client network. However, many of the larger schools visited that had significant Fat Client solutions in place also had remote distribution and installation capability for these files, and therefore did not report any particular advantage on the Thin Client network from a security consistency perspective.
- Deliberate tampering: Thin Client networks also are generally 'locked down' by default, delivering a standard desktop. The ICT co-ordinator at School 4 commented: 'We used to have glitches all round the building; children who played with PCs at home upset settings, desktop settings. You name it, they managed to do it. We don't get any of that now. Everything is tightly tied down so they can only run what we want them to run. They can only access what we want them to access.' School 8 also reported that they had

experienced significant issues with pupils exploiting the vulnerabilities of the previous environment and sabotaging files systems and pupils' stored work.

6 Technical support

6.1 The support provided

All primary schools used service providers for technical support, with half of these schools also having some form of in-house support for more routine problems and maintenance. One primary school (School 2) found that one on-site visit a week from the technical support company was all that was required to maintain the system, because it was so stable.

Of the eight secondary schools, only two used any form of external provision for technical support. School 5 received telephone advice from a company free of charge in return for feedback on the system, and School 9 used pre-purchased credits for third-party technical support. The remaining schools preferred to use experienced in-house technicians to provide the support they required, though some still retained a relationship with their supplier for software patches and network upgrades.

All schools upgraded and deployed new software centrally, making technical support easier. The same benefit can also be achieved on appropriately configured Fat Client computers, though some additional time and effort is required to download the software onto each computer.

6.2 Time on support

The nature of schools that operate Fat Client systems tends to involve 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.

As nearly all the Thin Client schools studied have expanded their ICT network greatly using Thin Client technology, none have been able to reduce the actual number of support staff (unless they have outsourced it). A further reason for not reducing the support staff is that schools have retained Fat Client computers, which were reported to need a greater amount of support because more can go wrong and because of the wider variety of hardware and software configurations that need to be managed**.**

Seven schools reported that the Thin Client network took less time per client device to support compared to their Fat Client computers. Although the schools may not have reduced the need for support staff, they have saved considerable amounts of support time, and so can manage a greater number of computers for the same cost.

One school (School 2) reported that little or no time was required to support the Thin Client network, other than one on-site visit from a technician each week. Other schools, however, found more support was needed. As these schools have hybrid systems, it was difficult to separate out the different amount of support required for each system. Schools did, however, give estimates.

For example, School 8 reported that supporting 120 clients on the Thin Client network took the same amount of time as supporting only 14 computers on the Fat Client network. School 5 reported that initially the school spend a lot of time refining the Thin Client installation, but had spent almost no time supporting the Thin Client devices in classrooms. This shows that

technical support staff are able to maintain a larger estate using Thin Client technology than would have been possible with a Fat Client network.

6.3 Training of support staff

In the majority of schools, technicians did not receive any training on supporting the Thin Client network. In at least four schools, training was provided by the supplier, but it was mostly written instructions and staffs were not particularly satisfied with this.

There were two reasons given why further training was not provided. The first was because support was provided externally (as in the primary schools). The second (for example, Schools 7, 8 and 11) was because the systems were built in-house by experienced IT staff. However, the implementation was not always successful (for example in Schools 8 and 11), so it could be argued that some of these staff could have benefited from more training.

7 Teaching benefits and issues

7.1 General observations on impact on teaching

Overall, those interviewed in the schools studied pointed to five major impacts on teaching using ICT:

- Lower costs per terminal enabled greater access to ICT for the budget available. This meant better terminal:teacher and terminal:pupil ratios, which enabled more teachers to use ICT in their lessons. It also enabled teachers to use ICT more frequently in their lessons.
- Greater reliability of terminals gave teachers more confidence to make use of the network than had been the case with the schools' previous networks.
- Where schools provided remote access using Thin Client technology, this gave teachers greater flexibility of working than before (Fat Clients can, of course, also provide remote access).
- A common software platform across the school (remotely facilitated by the Thin Client centralised system) encouraged greater use of ICT by teachers.
- The quieter and cooler environment enabled by Thin Client terminals makes them more appropriate for use in the classroom and other locations. School 7, for example, found that in areas like libraries, Thin Clients are thought to be a real advantage in terms of noise.

These factors had combined to enable schools to make more use of ICT in lessons and in the preparation of lessons. Although these benefits may also be true of extensive and well managed Fat Client networks, all the schools reported that it was much more difficult to provide these benefits with Fat Clients because of the need to update and oversee all machines and software (terminals) on a very regular basis.

Several schools had anticipated being able to use all their existing software on the 'new' Thin Client network and this had been a main requirement influencing their choice of which system to acquire. However, following installation some features of the more powerful educational software applications would not run as reliably as they expected. This implies that extensive pilots and trials should be conducted before purchase, running several Thin Client machines at the same time with such software in order to judge if it will run on a fully operating system with many simultaneous users.

One general point of interest is that a significant proportion of the teachers interviewed in the schools were not aware of the system being Thin Client or Fat Client. Their main concerns were about using ICT which was reliable and could be used as they wished in their teaching and for administrative purposes. Many of the comments related to the reliability of the network rather than the particular type of network being used.

7.2 Widening access

As mentioned above, all schools wished to increase the access to ICT and chose Thin Client technology to help them do this because of the lower cost per terminal. The greater number of terminals in the school, appropriately positioned (either as terminals in the classroom or

computer suites or roaming laptops acting as Thin Client terminals) has enabled teachers to make more use of ICT in all aspects of their teaching.

The places where Thin Clients and Fat Clients were used varied in each school and also upon the way in which the school's ICT resources were deployed. The primary schools had extended their ICT resources to include Thin Client networks where there were no IT networks at all previously. They were therefore also able to put more in resource areas such as the library and other areas in the schools.

The headteacher of School 10 reported that greater access had changed the way in which the whole school worked, and through this the ways of teaching had also changed. Due to increased access to hardware and software, teachers' ICT skills were improving, with some teachers previously nervous about using ICT now confident in its use. According to the Head of IT in School 6, 'The network has had a positive impact on teaching because as teachers become more familiar with it they become more innovative. There is more risk-taking [and they are] not afraid now. Also the teachers feel less threatened by pupils who can do all kinds of things which teachers don't have time to learn.'

7.2.1 Remote access

Eight schools reported that teachers could access the Thin Client network from home. School 7 had found that Thin Client technology could be used to provide applications to students' homes via broadband. Remote access was provided in one of two ways: either a Fat Client machine runs local applications and accesses data on the same file server that also is accessed from Thin Client terminals, or by launching a Thin Client session from the Fat Client computer, which gives users access to everything they would get on a dedicated Thin Client terminal (in other words, both applications and data).

Although similar functionality is available when remote working using Thin Client or Fat Client technology (assuming the Fat Client has all the applications required on it), the Thin Client suppliers provided a reliable and uniform system with appropriate support which encouraged this use of networks and servers which had not been the case with many of the schools' previous IT providers. An example of such reliable service was with School 12 whose Fat Client system crashed and they were unable to get the then provider to repair it in time for the pupils' examination work. This led them to contact several Thin Client suppliers, one of which demonstrated then and subsequently that they could provide both a local and remote resource which would be maintained and which would be highly reliable.

Having remote access to the network has had a noticeable impact on the ways in which teachers are working. According to School 12's ICT co-ordinator, remote access to the school's network has spawned new methods such as marking homework on Tablet PCs and liaising with groups of pupils in between lessons. A similar benefit was also reported by School 6, which claimed that the greatest benefit of the Thin Client server was by providing remote access to teachers from home. The result of this has been to introduce much more flexibility into the way in which teachers can work. It has given them much greater access to the ICT resources and enabled them to prepare lessons and mark homework online, so access can be 24/7 if desired. The same benefits can, of course, be achieved using Fat Client networks, but the schools reported that the standardisation of the desktop and the reliability of the network provided by the Thin Client server has encouraged extensive out-of-school access which might not have been achieved had these schools retained the Fat Client network.

In addition, the researchers note from wider market knowledge that Thin Client is marketed as having two major advantages for remote access. The first is that it is bandwidth efficient and therefore works well on narrowband connections. The second is that the data remains in the organisational environment and within its security boundaries. The growing prevalence of broadband is reducing the first advantage. The security of management information systems might seem attractive for the second reason, but they are generally not supported on Thin Client networks, so the researchers note that these are not necessarily key benefits for schools, as broadband access is increasing and most management information systems need to run on Fat Client technology.

The ability to deliver Thin Client sessions to low-cost machines has enabled School 11 to deliver an IT experience in the home to financially disadvantaged children who would otherwise have no access to technology outside school. They have enabled this through the use of a highly 'locked down' set of laptop devices through which children can dial up the internet using a school sponsored and funded ISP account. The laptop only enables a secure connection to school resources that will allow basic desktop applications to be used and provide access to the internet for homework research etc. This internet access is still, however, subject to the controls imposed by the school's own security systems and those provided at a Local Authority level. The machines cannot be used to install local applications.

7.2.2 Benefits of wider access

The case studies show that additional benefits of this improved access to ICT (which can be true of both Thin Client and Fat Client networks) included the following:

- Teachers were able to prepare lessons on computers from home, the library or staff room and these can be uploaded onto the network before the lesson.
- Teachers were able to monitor pupils' progress and prepare reports on the school's network from home in the evenings or at weekends.
- Teachers could communicate with pupils outside lessons more easily.
- Pupils could access files and information whilst working on homework and project work on terminals connected to the school's network.
- More flexible ways of working with ICT were enabled which are not dependent upon having to be in school and/or in a very limited choice of rooms.

7.3 Uniform and reliable provision

A Thin Client network delivers a standard front-end to each terminal, which individuals cannot change or customise (unless the individual is allowed to set their own preferences which can be loaded at the start of each session). In other words, Thin Client networks provide, by default, uniform provision and locked-down terminals. Both these attributes can be delivered on Fat Client networks as well, but it requires more expertise and control of the network to achieve the same result.

Uniform provision and locked-down terminals enabled the schools studied to create a standard environment, which meant that teachers knew what to expect on each terminal and in each teaching environment they worked in. Crucially for the teacher, all resources are made available from all terminals at all times. Coupled with the reliability provided by the Thin Client network, this helped build their confidence, secure in the knowledge that their lesson plans should work in practice. For example, School 10 reported that the greatest

impact on teaching was related to the greater control which teachers had over their lessons, because it was not possible for pupils (or teachers) to 'tinker' with the terminals. Teachers were able to control what was on the screens (again, this is also possible on a Fat Client network). This uniform and controlled provision helped the teacher retain control of the lesson and ensure that pupils remained on task. The headteacher of this school reported that 'standardisation of the ICT resources… enabled all staff to make better and more confident use of ICT in their teaching'.

7.4 Staff training, attitudes, confidence and motivation

For the schools that implemented a network that delivered a standard Windows desktop environment for the Thin Client terminals, schools reported that no training was required and they therefore found little or no resistance to the implementation and take-up of the network. However, this finding need to be tempered by several interviews, where teachers complained about multimedia not working and raised concern about not having a wider range of software titles available on the Thin Client network.

Schools adopted different approaches to training staff to use the Thin Client technologies. Firstly, as far as the ICT team were concerned, most of them already had substantial experience in using Fat Client networks and therefore needed only limited training in how to use the new network. Some suppliers provided training at the beginning for all the staff in the school, and this was easier to organise in primary schools. For example, for School 4 (a primary) training was given to all staff face-to-face on how to log onto the network and access the files. It is now given in-house where required and supplemented with external training where specific application training is needed. New software is introduced at staff meetings and followed up with individual teachers. In School 12 (a large community college) training was not organised across the school because most teachers already had ICT skills and experience, and training was provided according to the needs of the individual instead.

School 6 encouraged teachers and pupils to teach themselves new IT skills. According to the Head of IT, who was also self-taught, 'the best students are also those who are self-taught. Some people are happy to be end-users. Others explore and find things out. The school actively encourages pupils to develop these skills so they can achieve at the highest level.' In School 3 (another primary), the ICT co-ordinator is also mostly self-taught but had some training when the new server was installed a year ago. The service contract includes training from the supplier.

What is noticeable about all the schools is that there was relatively little mention, especially in the secondary schools, about the training needs of teachers to learn how to use new software on the network in their lessons. According to the questionnaire returns, apart from School 3, most of the educational software in use on the Thin Client network is generic software such as spreadsheets and presentation software. This suggests that the Thin Client network is not bringing much new educational software into schools.

Greater concern was raised by staff in some of the schools that made use of Open Source software. School 1, for example, abandoned its use of Open Source software because of resistance from its staff. Those interviewed in School 8 wanted more training on using the resources that were compatible with the Open Source software so that they could make greater use of them in lessons. In the same school, staff preferred to use their laptops in Fat Client mode so that they could use the Windows-based software, rather than retrain to learn another system.

This suggests that staff attitudes are more positive where little change is required. Those schools that did change the look and feel of the terminals (because of different operating software) encountered more resistance.

7.5 Range of software used

An important finding from these case studies was that those teachers who wanted to focus on using the Thin Client networks tended to confine their and their pupils' uses to the generic software which ran easily, such as internet, email and office software. Other teachers reported mainly using the interactive whiteboard and were directed to use software provided on the local stand-alone machine, which tended to be presentation or subject-specific software, and internet access.

One school (School 10) in particular discussed the software constraints in great detail and was aware of the limitations to their teaching imposed by the limited scope of software available on their Thin Client network. One interviewee in School 3 reported, 'As a purchaser of software it is more frustrating because many products the school want to use won't run on the network… so many suppliers are not interested in supporting their software to run on Thin Clients'. The same school noted that in particular, this applies to the use of some measurement and control software.

Further findings from schools included the following:

- School 4 noted that performance issues remain where resource-intensive applications are used, which including interactive internet services.
- In School 5, according to the headteacher, there is continuing uncertainty about whether the Thin Client network will be able to keep up with the latest software or whether it will always be necessary to have a mixed economy of Thin and Fat Clients.
- In School 9, where applications are certified for support over the Thin Client networks (either by the software developer or Thin Client network provider) the deployment is straightforward. Where software is not certified, this will be tested within the Thin Client network, and should the implementation not be successful, then a Fat Client deployment will be undertaken. Staff reported some limitations to the software that can be used on the Thin Client network. Some older programs do not work well on the server and although the network manager tries to check compatibility with the Thin Client supplier when software is purchased, some will only work very slowly. Departments can arrange to use the ICT suites to deliver teaching using Fat Client applications specific to that department. The technology department uses control modelling packages and CADCAM which do not run on Thin Client.
- School 9 also found a problem with licensing: all applications that are made available via Thin Client require site licences as they are available to all. Previously, where a very small number of users were anticipated, the school would have purchased user licences, which would have been more cost effective. (It is not clear why the school has not explored purchasing concurrent user licences rather than site licences.)

In contrast, some schools had found advantages relating to software and Thin Clients:

- Those interviewed in School 2 reported that most software can be run on Thin Client systems. Though this school found that some programs do have problems, staff liaise with the companies to address this. Those interviewed thought that there had not been any significant problems with software because the school was realistic when using it.

They also investigated what would work before committing to it. Software is trialled by the school for companies and feedback is given to help improve the service.

- Those interviewed in School 7 reported that more money is being spent on software than used to be. This is because the Thin Client equipment lasts so long that money is available from the savings in maintenance and replacement.

It was significant that, in describing their ICT uses with the Thin Client network, very few of the schools talked about a wide range of subject-specific software. As with previous network provision in schools, many teachers seemed to be guided by central policies and senior management about what they could use and what was desirable to be used in their subject. This approach, which needs further investigation, suggests that because of the Thin Client centralised system, individual teachers claimed no or little ownership of their ICT teaching resources. Previous research (see for example Cox and Webb, 2004) has shown that such a situation can result in poor or superficial uses of ICT in teaching.

More in-depth research could be helpful to see whether there is any difference in outcomes from each of these approaches.

7.6 Peripherals

The use of peripherals such as memory sticks, digital cameras or data-logging equipment varied widely between schools. Where a school had converted many PCs to become Thin Clients on the network, they still had access to the USB ports. Whether they could use these or not depended upon the policy of the ICT co-ordinator and the senior IT management team.

Five schools reported that their Thin Client network and terminals did not support any peripherals. It should be noted that all the case study schools operate hybrid systems, so this is less of a problem than it might be. For example, although the Thin Client terminals in School 11 do not support peripherals, the high penetration of Fat Clients means this is not a major restriction. In that school all devices such as interactive whiteboards, digital cameras and camcorders, and external media (USB memory sticks and CDs, for example) are interfaced via the Fat Client network. If a teacher wishes to make use of the data gathered from the peripheral on a Thin Client terminal, the data has to be stored on a central file server, where it can be accessed by both Thin and Fat Clients.

The remaining schools reported that they did allow peripherals on the Thin Client network. This has been enabled either through USB ports on more recently purchased Thin Client terminals or the use of legacy machines with these ports enabled. Despite having this functionality, there were some problems:

- All schools that reported using interactive whiteboards did so over a Fat Client network. Not all interviewees were clear on the reason for this. Where they were aware, those interviewed thought it was because the whiteboard control software is reliant on the use of specific interfaces/drivers for the board that are not supported on the terminals deployed. It is likely that in future generations of terminals, support for this functionality will become available. Some schools used the teacher's laptop to run the whiteboard sessions and therefore no additional desktop systems were required. Work undertaken on the whiteboards could be saved to the central file servers where laptops were connected to the network. Through this mechanism, files could therefore be made available to pupils via the Thin Client network for terminal-based work at a later date.

- Those interviewed in School 3 reported that some software providers are very unhelpful in getting their products to work on Thin Clients. This especially applies to the use of some measurement and control software. Digital cameras and video cameras can theoretically be connected although school working practice is for the technical support team to upload these images centrally to the file server. The performance of these media-rich applications over the Thin Client network is also a limitation, as explained above.

7.7 Inclusion

Not all schools had explored the use of special educational needs software and hardware on the Thin Client network. Some schools (for example, School 9) had a policy of not using these packages on the Thin Client network. Other schools had been more proactive. For example, School 11 has tested a range of features to facilitate inclusion including specialist keyboards and contrast controls. They found these all worked equally effectively on the Thin Client network and on the Fat Client network.

It is concerning that some schools have not looked at inclusion issues for their Thin Client network: this is not good practice when deciding what type of ICT provision to put in place. However, those schools which have explored the issue have found that Thin Client technology is not necessarily a barrier.

7.8 Impact on the teaching environment

Four schools reported improvements in their environment as a result of implementing their Thin Client network. School 7 thought that the classrooms with Thin Client technology were quieter and cooler. One teacher said, 'In the classroom the peace is remarkable compared to a room full of PCs.' This was also reported to be the case in School 3.

The teachers interviewed in School 9 thought that the computer rooms which have the Thin Client terminals in them are more pleasant to work in because they are cooler and quieter and there is no need to install air conditioning. This creates a more conducive atmosphere for learning to take place. Schools 3 and 5 also reported that the Thin Client terminals took up much less space so that pupils had more room for their other work, such as books and handouts while working at the terminals.

These are positive benefits for teaching and learning, though not all teachers reported that the environment had been an issue before the Thin Client network was introduced.

8 Learning benefits and issues

8.1 General observations on impact on learning

The schools studied pointed to greater access and greater reliability as key influencers on pupils' use of Thin Client technology. The greater access and reliability gave learners more opportunity to use ICT in learning a range of subjects and, because they work with fewer problems, they have greater time to spend on their tasks. Whilst a large and well managed Fat Client network could offer the same benefits, the Thin Client secondary schools studied found that they were able to deliver more access for their budget using Thin Client technology. However, the Thin Client primary schools studied had a higher TCO per terminal and per pupil than their Fat Client counterparts.

Apart from ICT skills, no schools were able to point to specific improvements in attainment as a result of implementing the Thin Client technology, though Ofsted had reported favourably on some of the schools' practice and outcomes in relation to ICT. However, the specific benefits identified below such as motivation, independence of the learner and more flexibility in learning will have a positive impact on pupils' learning generally. For example, School 3 has always observed that boys approach using ICT differently to girls. According to the headteacher, 'difficult boys became stars, enjoy that type of learning.' In the ICT co-ordinator's view, 'It has had a significant impact on them, a very big impact with disaffected boys.' Since the network has been installed, boys now consider 'it's cool to be brainy so boys are very keen on learning ICT. In the school boys are now not under-performing as compared with the national average, which has improved since a few years ago' (headteacher).

According to School 5, pupils who used to be very slow at using computers have significantly improved their ICT skills because they get regular practice with ICT. This has a knock-on effect of helping them use ICT in lessons to learn other subjects when they do not have to concentrate on manipulating the software. Secondly, the access which the older pupils have at home, enabling them to upload homework, work on school projects, access the school network and all its applications, lets them work more flexibly at times when they are most amenable to learning (ICT co-ordinator).

School 11 pointed out a key problem with their Thin Client technology: teachers interviewed thought that Thin Client was not meeting the changing nature of examination courses and the type of software that was now being more widely used. In a recent examination, pupils could not put sound onto their PowerPoint presentations so they had to write about this in their evaluation. Some of the pupils are quite technologically capable and become frustrated by this. It was thought by teachers interviewed that it would be difficult to deliver the Diploma in Digital Applications using Thin Clients and they also had concerns about Key Stage 3 online testing.

8.2 Pupil attitudes and acceptance

In general, pupils made good use of the additional technology available to them and the Thin Client technology had been well received. The overall increase in ICT resource because of the Thin Client contribution was reported by the schools to have several beneficial impacts on the pupils' attitude and learning:

- Pupils' ICT skills were improved to above national averages because of the regular and frequent uses of ICT.
- Pupils were able to work more flexibly, especially where out of class work (home-work or self-study) was concerned because of having access to the school network at any time, and from anywhere.
- Collaboration amongst pupils was increased because of the ability to collaborate outside of school hours on projects and collaborative homework.

However, there were examples where acceptance had been questionable, and there are lessons here for other schools considering whether and how to implement a Thin Client network:

- Server specification: in School 8, for example, the school undertook their own design, based on using equipment they already had. This was not of a high enough specification for the purpose and as a result the initial network had very significant performance issues, causing frustration for pupils and teachers alike.
- Open Source software: this can run on both Thin and Fat clients, and the decision to use it is independent of deciding to implement a Thin Client network. However, it is worth noting that in School 8 pupils were given the software to load onto machines at home but declined to do so as they preferred to use more familiar Windows-based products. Pupils in the younger years, however, are more accepting of the software.
- Transferring work to home: School 9 reported that acceptance of the Thin Client technology had been good, though some pupils were frustrated at the difficulties they faced transferring work from the school network to home, owing to the lack of external disk drives and USB support on their Thin Client network.
- Accessibility: for very young pupils there was difficulty logging on and managing the general interface provided by the Thin Client server because of limited reading skills. The same issue is likely to arise with Fat Clients, depending on the user interface.

8.3 Widening access

All schools said that increased access was a key objective in deciding to implement a Thin Client network. Though it is difficult to link achieving this objective to academic attainment, schools did put forward some positive evidence. For example:

- School 2: owing to the greater access to computers, the pupils' skills have come on 'in leaps and bounds' (ICT co-ordinator). When the school was last inspected by Ofsted it was highlighted that in Year 4, the pupils were working at level 4 on many aspects of IT.
- School 10: wider access has raised the level of use of ICT within the school and was providing more opportunities for pupils to diversify their learning and choose where and when this was done.
- In School 1 Ofsted reported that standards reached by pupils in ICT at the end of Years 2 and 6 were above the level expected for pupils of that age. It was also noted that because the pupils had access to two platforms (Thin Client and Fat Client) they were able to select programs with ease and older pupils, who had made the transition to more complex software, had developed transferable ICT skills very well. Although this is not directly attributable to Thin Client technology, the school thought it would not have afforded the extent of coverage provided by the network had it not selected Thin Client technology.

- In School 4, in addition to the network and the PCs in classrooms, there are also terminals in the library, which has resulted in pupils researching topics and doing more investigations independently. The more frequent access to ICT has also improved the flexibility of teaching and provided more diverse experiences for learners. One of the teachers reported that she would like to see a lot more terminals 'dotted around the school so that pupils could finish work off' (class teacher).

Often it is a range of factors that come together to deliver high standards of attainment, and isolating the impact of Thin Client technology and the wider access that this provides is not possible. For example, School 7 is a high-performing school with 80 per cent of Year 11 pupils achieving five A* to C grades in 2005(without including the effect of GNVQ and other Vocational GCSE equivalent courses). This was nearly ten percentage points up on the GCSE results in 2004. Teachers interviewed thought that whilst this was due to a combination of factors, there was a strong feeling that some of this success could be accounted for by the extensive use of ICT in lessons. Staff interviewed thought that their colleagues would say that the success was down to the use of laptops and digital projectors making lessons better prepared and better paced, including more variety and being more motivating for the pupils. The Virtual Learning Environment enabled exchanges of coursework between staff and pupils to revise and improve. However, it would be very difficult to isolate the effect of specifically Thin Client technology as opposed to the more extensive use of ICT.

8.4 Confidence and motivation

Teachers reported that confidence and motivation of pupils had improved in four of the schools studied, and no schools reported that these had declined since Thin Client technology had been introduced. Reasons cited for improving confidence and motivation included:

- a standard desktop: teachers in School 9 thought that the common desktop had improved pupils' confidence, as they knew what to expect when they logged on and could pick up where they left off previously
- reliability of the network: for example, School 7 reported that reliability of the school's Thin Client network helped learning as the pupils were not distracted by the system not working
- the use of the network to prepare and share work: School 10 reported that pupils had used the Thin Client network not only to prepare work, but also to share it with their teachers. This had motivated them to produce higher quality work. This is, of course, possible on Fat Client networks as well.

8.5 Autonomy of the learner

The wider access to ICT was also reported by many of the schools as increasing the autonomy of the learner. As explained above, pupils could access the network outside of lessons, enabling them to continue work on specific projects and topics which encouraged them to be more responsible for their own learning. Teachers have expressed surprise at how independent some pupils have become.

For example, in School 12 'Students even come in at 8am to use the library. It's quite a shock really. Culturally our school has not been one where it's cool to ask questions, do extra homework or be top of the class. Using the Thin Client as a learning aid is breaking down that culture. Pupils learn at their own pace without the social pressures from their

peers and we see them concentrating and achieving more because of it. The special needs pupils can also learn alongside the others, being shadowed and going over work if they need to. They don't have to be taught separately which is another saving to the school as well as a benefit to the pupils." (Business manager – School 12).

This greater access resulting in more autonomy of the learner was also reported to lead to an improvement in the pupils' ICT skills. For example, School 6 reported that the greater flexibility 'enables pupils to do their homework after tea by remote access. This is an improvement because they do not do their best homework rushed at school when needing ICT access." (e-college manager – School 6)

Even in primary schools, teachers reported on the greater independence of their pupils. For example, School 4 reported that a major benefit is that pupils can do more individual work and monitor their own learning. The SEN co-ordinator reported that 'since the school has had the Thin Client network, when I run special sessions other pupils want to join our (SEN) group because the children are using the equipment well and this is raising their confidence and self-esteem' (SEN co-ordinator).

However, one limitation reported by this school was that the very young pupils cannot log on easily because of their limited literacy skills. This can restrict their access to the network although they show encouraging determination in trying to master the logging-on process because of the strong motivation to use the technology.

9 Management and administration

9.1 General observations on management and administration

Much management and administration in schools can operate over the Thin Client network: email, lesson planning and similar activities are not hampered by the known limitations of Thin Client networks, provided the individual is able to log on to the network. However, in 10 out of the 12 schools the management information system (MIS) ran over a separate Fat Client network. These issues are discussed in more detail below.

9.2 Management Information Software

As has been mentioned, ten schools maintained separate logical (though not physically separate) administrative networks using Fat Client technology. The reasons for this fell into three categories:

- Local Authority stipulation: some schools' Local Authorities operated their own Management Information System, and insisted that the schools keep Fat Client computers to input and access data held on that system.
- Lack of support: most providers of school MIS do not support their software when it operates on a Thin Client network, forcing schools to retain a Fat Client network. For example, School 9 found that their management and information software was not supported by the provider when deployed on Thin Client. The school therefore retained a Fat Client network to support this, although they had found that the software could be accessed from Thin Client terminals.
- Fear of network failure: School 9 also noted that one benefit of having the MIS operating over a separate Fat Client network was that if the Thin Client network went down, they would still be able to continue to use the administrative system.

Four schools reported using their MIS over the Thin Client network. In School 11, the school's management information system runs predominantly on Thin Clients. However, due to the resource-intensive nature of the school's management information system application, the software has a dedicated Thin Client server. In School 12, the school runs its MIS on Thin Client and has plans to extend access to parents.

9.3 Administration

Though most schools used the Fat Client network for the MIS applications, many use the Thin Client network for other administrative tasks. In the main, these tasks can be equally well carried out on Thin and Fat Clients. For example, in School 7 staff reported using the Thin Client network to do a variety of tasks including pupil lists, labels, trips, report writing, editing and printing – these could equally well be done using Fat Client technology. Those interviewed in School 10 were very positive about this aspect of the contribution of the Thin Client network. For example, the geography teacher found she completed the administrative side of her work much more quickly than before. The headteacher reported that there was a significant change in management and administration within the school (not entirely due to the Thin Client network) as a result of every teacher having his or her own laptop. These were connected into the Thin Client network and together these resources had changed the way teachers communicated with each other and with pupils and provided a much more flexible way of working.

A major benefit reported by School 12 from having more ICT resources provided by the Thin Client network was that it enabled a different method of supply cover to be used when teachers are ill or away from school for other purposes. The previous supply cover budget with 103 teachers was very high, at £150 per day each time someone was away. The Senior Management Team reviewed this expenditure and concluded that it would be more cost effective and educationally beneficial to replace this ad-hoc supply cover scheme through the use of subject work on the network. The school has appointed two permanent assistant learning managers to supervise two rooms (of 60 terminals in each) in which up to 7-9 classes for Years 7, 8 and 9, can be working whenever a teacher is away. This arrangement both provides much greater continuity in teaching and also reduces costs to the school.

10 Total cost of ownership

This section reports on key findings from the research comparing Total Cost of Ownership in ten Thin Client case study schools with nine Fat Client schools. Appendix 1 gives the full findings.

10.1 The TCO Concept

- When considering the cost of procuring and running an ICT network, it is important not to consider just the purchase costs. Becta notes that the total cost of ownership (TCO) of a school's ICT infrastructure is ...the sum of all the costs associated with the purchase, implementation, operation and maintenance of the service. Some of these costs can be easily quantified while others, although significant, are much more difficult to identify and quantify.
- Capital expenditure on ICT in schools and colleges represents only a small part of the ongoing costs of incorporating technology into education. Decisions made today with regard to technology, management, curriculum, policy making, ICT training and support, will have a direct influence on the costs an institution will incur tomorrow. Understanding the relationship between these decisions and future costs is becoming increasingly important. Senior managers in schools are aware of the need to plan effectively and ensure that ICT provision is sustainable in the long term. (Becta, 2006b)

To this end, Becta provided a tool to help schools evaluate the Total Cost of Ownership for their ICT infrastructure. This section of the report is based on the results that have been obtained from the data submitted by schools to the Total Cost of Ownership (web based) Tool provided by Becta for the project.

10.2 Scope

All figures and facts quoted within this section are the property of the subject school and no manipulation or amendment has been carried out by the researchers.

Some schools participating in the survey were unable to provide the level of detail required by the TCO Tool and incorporated detail at a higher level. They therefore either left the elements blank or entered 0 (zero). Where comments are only made at the higher level, it is because comparisons at the detail level could not be satisfactorily made.

The number of schools participating in the Thin Client and Fat Client data collection is small. When these are split between Thin Client and Fat Client and primary and secondary, the four groups are only large enough to give a potential indication as to the trend. It is not practical to consider primary and secondary together as the demands on the ICT systems are significantly different and cannot be compared.

Furthermore, each school within the sample is unique in its own context and as such comparisons cannot be considered as anything more than an example.

None of the results or analysis within the TCO study can be considered to be statistically representative of the entire school base. At best, the results give an indication as to the possibility of a trend. In addition, each school is unique, dealing with its diverse pupils needs in different ways.

10.3 Key findings

10.3.1 ICT Budget

In secondary schools, the spend for Fat Client provision appears, on average, to be greater (including as a portion of the school budget) than for Thin Client provision. The range of the budget spent on ICT as a percentage of the total school budget is bigger for Fat Client schools than for Thin Client. It is also apparent that more is being spent per staff member and per pupil in Fat Client schools than in Thin Client schools.

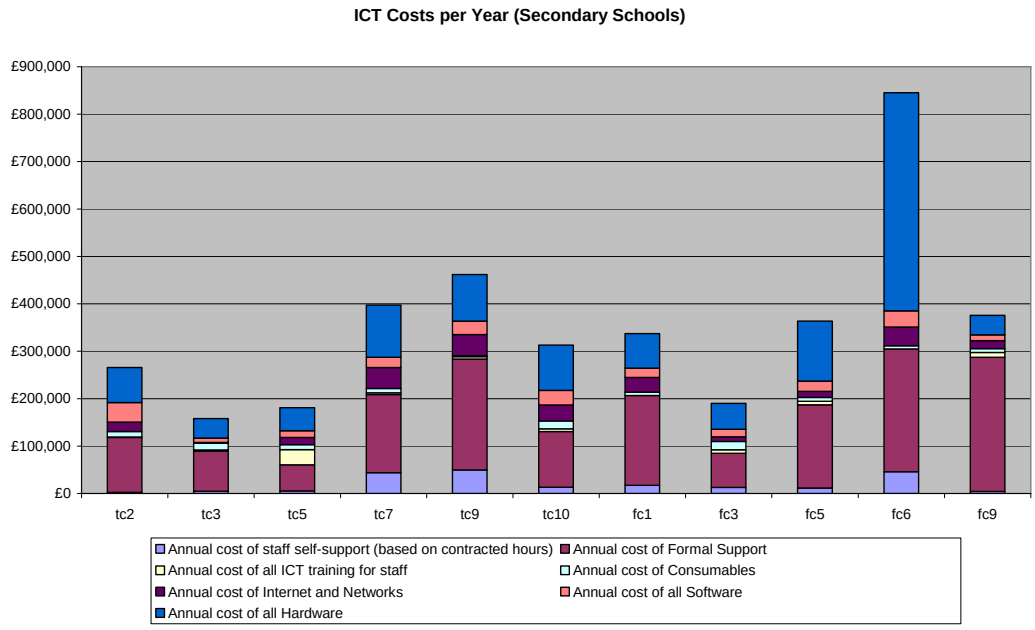

Figure 10.1: ICT Costs per Year (Secondary Schools)

As shown in Figure 10.2, there is significant variation of the annual spend incurred by primary schools within the sample. The variation in spends between the schools makes it difficult to draw any conclusions about trends.

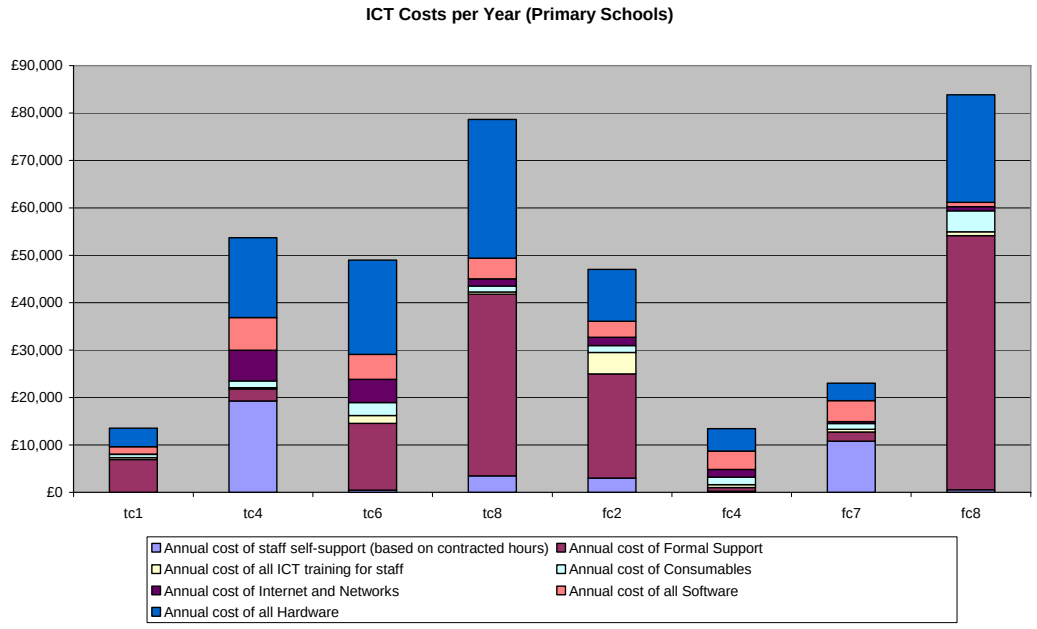

Figure 10.2: ICT Costs per Year (Primary Schools)

10.3.2 TCO per PC

Figure 10.3 shows that the Total Cost of Ownership per personal computer is nearly 40 per cent less in Thin Client secondary schools than their Fat Client counterparts in this study. However, it does also show that in primary schools, the Total Cost of Ownership per terminal for Thin Clients is slightly higher than their Fat Client counterparts. The number of schools is too small to conclude whether this is true of all Thin Client implementations in primary schools.

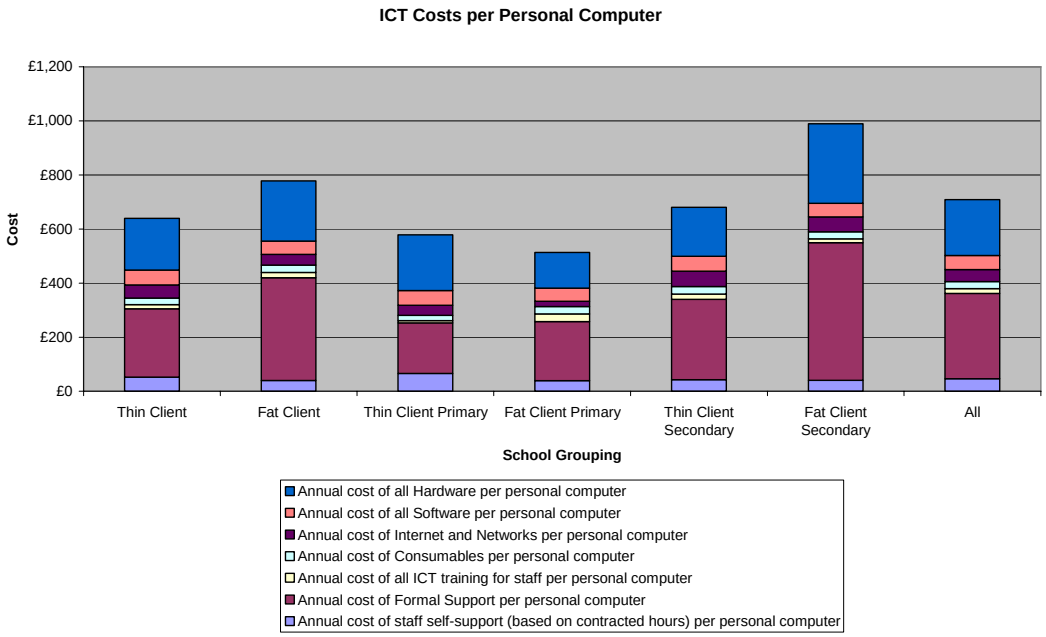

Figure 10.3: ICT Costs per Terminal or Personal Computer

10.3.3 Support costs

Figure 10.4 show that support costs are a significant factor in all the schools. It provides an indication that the Thin Client primary schools studied spend a lower proportion of their budget on support than the Fat Client primary schools studied. This may be because they outsource their support, and are therefore able to secure what they need at a lower price than if they were to provide it internally. This factor is marginal for secondary schools but again Figure 10.4 does show a slight difference.

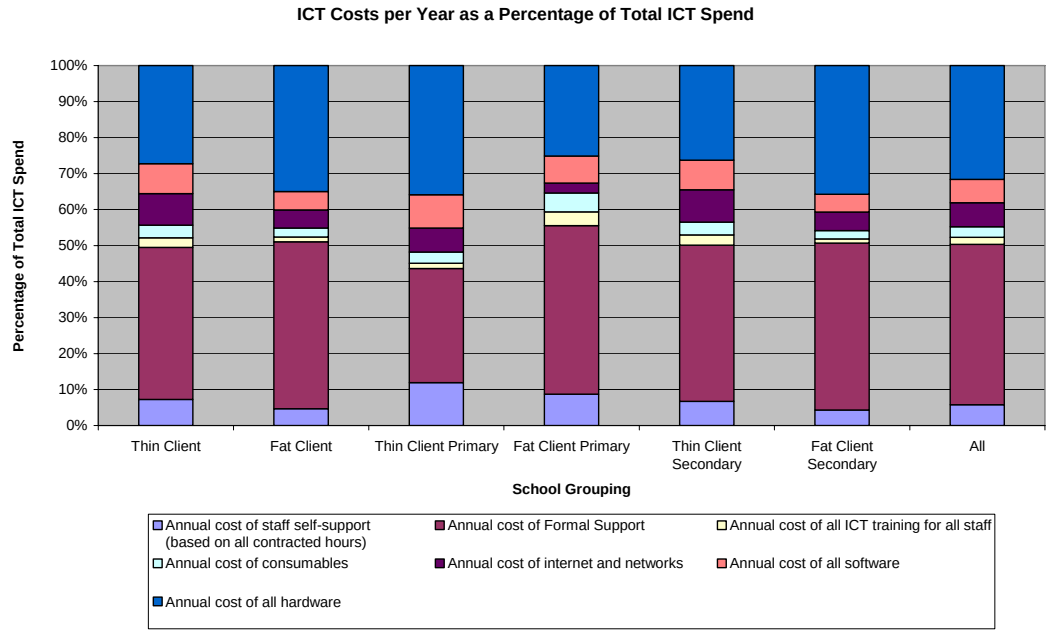

Figure 10.4: ICT Costs per Year as a Percentage of Total ICT Budget

10.4 Observations

Based on the analysis of the TCO data the following observations have been made:

- The Total ICT costs per staff member (excluding the hardware element) are very similar for primary schools and marginally less expensive in secondary schools between Thin and Fat Client. However, once hardware is included, Thin Client becomes more expensive for primary schools but less expensive for secondary schools.
- The support requirement in terms of cost is less for a Thin Client network in primary schools, perhaps because the schools have found that outsourced support is cheaper than providing the support internally.

11 Lessons learned / recommendations

There is no 'one size fits all' solution for schools. What is clear from the twelve case studies is that a great deal of research and effort has been put in by staff in the schools to determine what their curriculum and administration needs are and how these can best be met. Great care has then been taken in developing a system that best suits those needs.

11.1 Recommendations from schools

All the schools interviewed were asked to provide advice for other schools considering Thin Client technology. The following list was put together from their response:

- **Visit other schools:** before implementing a Thin Client network, talk to someone who already has already implemented one in their school and arrange a visit. Talk to them about their experiences and use this to help shape your own objectives and approach.
- **Define clear objectives for what you want:** many of the schools in our study said they had a clear single objective of resolving the requirement to expand access to ICT whilst keeping costs to a minimum. Schools need to be clear about the details of their objectives and not forget complementary requirements such as more space or support staff.
- **Ensure you have appropriate experience on your team:** for some schools, this may mean in-house expertise whilst others may rely on external expertise. Decision-makers in the school need robust advice, and should consider carefully how best to secure that. In addition, schools should consider whether technical support should be delivered in-house, by an external provider or by a mix of the two. Whichever solution, it is important to make sure that you have the level of support you need to ensure that the network works well and is properly maintained, to prevent future problems arising.
- **Have a structured design process:** decide what outcomes you want and ask the people with the appropriate expertise to design your system:
    - Effective network mapping needs to take place to see what is required and where to give maximum accessibility and use
    - The use of space needs to be considered before the network is installed: a good layout is needed to make full use of the Thin Client system; good utilisation of space gets teachers on board
    - Undertake a full-scale and forward-looking audit of the school's aims and its perceived needs in three to four years' time. Use this to plan how to accommodate changes to the curriculum, and hence the school's ICT need. As the curriculum becomes more sophisticated in its use of ICT in many subjects, multimedia use could become more of an issue, as more processing power is needed.
    - Ask a trusted third party to scrutinise the planned design
    - Review all of this, and ensure it meets your needs.
- **Don't underestimate the capacity of the servers required**: where schools ran into difficulty with their implementations, it was usually because the servers were underspecified (in some cases old computers). Those who did not have these difficulties had procured servers with sufficient capacity not only for current needs, but also future expansion.

- **Consider your educational software requirements**: not all software is designed to work on Thin Client technology. Check with your intended network provider about the titles you wish to run on it. Ask them to organise a demonstration for you, so that you can check for yourself that they work. Make sure you see the software running on several machines at once to check its speed when being used by many users. One school in our study advised others to remain focused on the types of software to be used: they thought it was better to have fewer pieces that work well on Thin Client and as proficiency increases, move on.
- **Consider a hybrid system**: this report has outlined a range of known issues that Thin Client technology currently faces (problems delivering multimedia and some terminals not supporting peripherals). Consider how other schools have dealt with these issues, and keep in touch with the latest developments on Thin Client technology as these problems may be resolved as servers and network capacity improve. (Some Thin Client terminals already offer USB access for a range of peripherals, for example.)
- **Consider the skills of your teachers and pupils**: if you are opting for Open Source software, you may need to do more retraining of your staff and pupils to cope with the new environment. Becta has provided independent advice on Open Source Software (Becta, 2005b).
- **Consider changing the way the school functions**: are there different ways of organising the school which could be supported by a Thin Client network? You could, for example, consider vertical curriculum teaching and managing supply cover.
- **Consult your staff and pupils**: if changing from a Fat Client network, consider all the pros and cons and share them with the staff. This makes for a more seamless transition.
- **Be aware of the Total Cost of Ownership**: the case studies suggest that the total cost of ownership in primary schools may be greater for Thin Client than for Fat Client. The opposite is true of secondary schools in this study. This may be because the greater size of the secondary school networks enables economies of scale to be introduced.
- **Consider the needs of all staff and pupils:** inclusion is not necessarily an issue on Thin Client networks, but schools need to ensure that their network is able to support pupils with special educational needs in the environments where that help is going to be needed.
- **Emphasise the benefits:** in the schools studied, greater access and reliability have resulted in improvements in the ways in which teaching and learning are organised which is having a knock-on effect on pupils' behaviour and learning.

Finally, schools may wish to consider their view of the future ways in which technology will go. Undoubtedly, server and network technology will improve, but will this mean that all multimedia applications will work on Thin Client technology in the future? The schools interviewed for this report were divided on this issue, and it is salient to note that one school is currently migrating from a Thin Client network to a predominantly Fat Client environment to be able to accommodate multimedia in all aspects of teaching, and as a result of very little requirement to teach standard office-type features.

11.2 Recommendations for industry

The researchers also offer the following recommendations to providers of Thin Client operating systems and educational software providers:

- Examining software compatibility: there are a range of different operating systems for Thin Client technology. It would be useful to those deciding whether to implement a Thin Client network in their school if providers of Thin Client operating systems stated which of the most popular educational software titles, as defined perhaps by Curriculum Online purchases, will work on their operating system.
- It would also be useful if providers of educational software worked closely with providers of Thin Client networks to ensure that their software is able to work on Thin Client networks.

12 Further research

This research has clarified a number of issues relating to the implementation of Thin Client technology in schools in England. However, there remain a number of issues that would benefit from further in-depth investigation and analysis to help schools and policy makers further understand the implications of this technology. The following areas are suggested:

- Exploration of the use of Thin Client technology in different subject areas: this research has highlighted areas where schools may find it difficult to teach subjects, owing to the limitations of their particular network. For example, music was commonly cited as a subject where the limitations of the servers' capacity to deliver multimedia applications to the terminal caused problems. It would be helpful to have further research to examine where the benefits of Thin Client technology particularly lend themselves to the needs of different subjects, and whether there are ways around the limitations other than those cited in this report.
- Investigation of schools operating solely in Thin Client mode: the researchers were not able to visit schools that operate completely over Thin Client because none were identified (four were initially thought to have only Thin Client technology in place, but on visiting this proved not to be the case). It would be helpful to undertake a few more case studies of schools operating solely on Thin Client technology, if they can be found, to see if there are further lessons to be drawn from these schools' experiences.
- Exploration of schools' decision-making processes: as outlined above, schools went through a variety of processes to decide on Thin Client technology as their solution, and then which company they should use to provide the equipment and which company to support it. Further research could be done to look in detail at the decision-making process.
- Examination of ways of meeting the limitations of Thin Client technology: this report suggests that schools are able to find ways of working around the limitations of the Thin Client network. Further research could explore whether those schools that taught in ways that did not require rich media software were limiting their pupils' ability to follow the National Curriculum in any way, and whether the style of teaching was any more or less effective compared to those schools using more demanding multimedia.
- Investigation of interactive whiteboards: given that a growing number of schools are investing in interactive whiteboards, schools' inability to get them to work on a Thin Client network could cause a barrier to further uptake of interactive whiteboards in schools wishing to go down the Thin Client route. Further research could be undertaken to investigate whether and how interactive whiteboards and their supporting software might work on Thin Client networks.
- Investigation of the scope and range of educational software which will run on Thin Client networks and identification of the specific reasons for other software not functioning adequately, which may not be due solely to limitations of Thin Client networks.

13 Notes on methodology

13.1 Selecting the schools

Schools were selected for the case study from a list of 50 schools that had completed data returns for the project review conducted for the first phase of the research, reported on separately. Schools were selected from those that had implemented Thin Client technology for the longest period of time, to make sure that sufficient years' worth of data was available for the Total Cost of Ownership element of research. A mix of primary and secondary schools were identified, to ensure that both phases of education were adequately covered, and a broad geographical spread was also sought, to ensure that the research did not draw on any one particular geographic region. These criteria narrowed the number of schools on the list to 25. All schools were approached, and 12 agreed to take part in the case studies.

13.2 Visiting the schools

Two visits were made to each school. The first, conducted by a researcher with experience in teaching gathered information about teaching, learning and administration in the school. This person conducted four or five in-depth interviews in the school, including:

- the headteacher
- the ICT co-ordinator
- one or two teachers
- one support staff member, if Thin Client technology is used for administration, or a teaching assistant if not.

The interviews were conducted using a semi-structured interview technique: an agreed set of questions framed the interview and enabled evidence to be gathered without constraining the interviewer or interviewee to sticking rigidly to the order.

The second visit was conducted by a member of the research team with experience of the technical aspects of Thin Client technology. This person spoke to the network manager or equivalent in the school, and secured a detailed audit of the network that the school had in place. This interview was also semi-structured. Where time allowed, this second visit included observing performance of applications such as multimedia packages to see whether it was tolerable. Also, where necessary, the researcher physically inspected the communications equipment at schools where the interviewee was not able to articulate network structure or other details.

13.3 Analysing the results

The interview notes were analysed for emerging themes and issues using a simple database to record and track key points.

13.4 Limitations of the methodology

Whilst the research methodology has produced rich and informative case studies, there are a number of limitations that must be recognised:

- Time: this was limited both for schools and for the research. This led to three key limitations:
  - The researchers were only able to interview five or six people in each school, of which only two or three were practising teachers. This meant that it was not possible to pinpoint the strengths and weaknesses of Thin Client technology in different subjects.
  - No pupils were formally interviewed.
  - Lessons were not observed directly.
- School history: three schools had not had a network prior to implementing the Thin Client network. This therefore means that of those interviewed, only those who had worked in other schools were able to draw comparisons with Fat Client networks.

14 Acknowledgements and disclaimer

Becta and the researchers wish to thank all twelve schools that agreed to take part in the Thin Client case studies. Nine of these schools wished to be acknowledged by name. They are:

The Camden School for Girls, London
Eggbuckland Community College, Plymouth
Egglescliffe School, Stockton-on-Tees
Heath Primary School, Derbyshire
Kirkbie Kendal School, Kendal
Parrs Wood High School, Manchester
Shakespeare Junior School, Hampshire
Solent Junior School, Portsmouth
Stoke Damerel Community College, Plymouth

The research was conducted 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.

15 References

Becta (2005a) *Functional Specification: Institutional Infrastructure, version A*, Coventry. Viewed online September 2006 at http://foi.becta.org.uk/display.cfm?cfid=87305&cftoken=aa1a180f133f04-98BBB0F6-CE49-5D96-D63B898B00CD8A9C&resID=14612

Becta (2005b): *Open Source Software in Schools: a study of the spectrum of use and related ICT infrastructure costs,* Coventry. Viewed online September 2006 at http://www.becta.org.uk/corporate/publications/documents/BEC5606_Full_report18.pdf

Becta (2006a): *Survey of LAN infrastructure and ICT equipment in schools*, Coventry. Viewed online September 2006 at www.becta.org.uk/corporate/publications

Becta (2006b): *Total Cost of Ownership.* Viewed online September 2006 at http://schools.becta.org.uk/index.php?section=tl&catcode=as_chr_02&rid=9650

16 Appendix 1 – Total Cost of Ownership

16.1 Introduction to the TCO Concept

When considering the cost of procuring and running an ICT network, it is important not to consider just the purchase costs. Becta notes that:

> ...the total cost of ownership (TCO) of a school's ICT infrastructure is 'the sum of all the costs associated with the purchase, implementation, operation and maintenance of the service. Some of these costs can be easily quantified while others, although significant, are much more difficult to identify and quantify.
>
> Capital expenditure on ICT in schools and colleges represents only a small part of the ongoing costs of incorporating technology into education. Decisions made today with regard to technology, management, curriculum, policy making, ICT training and support, will have a direct influence on the costs an institution will incur tomorrow. Understanding the relationship between these decisions and future costs is becoming increasingly important. Senior managers in schools are aware of the need to plan effectively and ensure that ICT provision is sustainable in the long term. (Becta, 2006b)

To this end, Becta provided a tool to help schools evaluate the Total Cost of Ownership for their ICT infrastructure. This section of the report is based on the results that have been obtained from the data submitted by schools to the Total Cost of Ownership (web based) Tool provided by Becta for the project.

16.2 Scope

All figures and facts quoted within this section are the property of the subject school and no manipulation or amendment has been carried out by the researchers.

Some schools participating in the survey were unable to provide the level of detail required by the TCO Tool but incorporated detail at a higher level. They therefore either left the elements blank or entered 0 (zero). Where comments are only made at the higher level, it is because comparisons at the detail level could not be satisfactorily made.

The number of schools participating in the Thin Client and Fat Client data collection is small. When these are split between Thin Client and Fat Client and primary and secondary phases, the four groups are only large enough to give a potential indication as to the trend. It is not practical to consider primary and secondary together as the demands on the ICT systems are significantly different and cannot be compared.

None of the results or analysis within this document can be considered to be statistically representative of the entire school base. At best, the results give an indication as to the possibility of a trend. In addition, each school is unique, dealing with its diverse pupils' needs in different ways. This makes it harder to compare Total Cost of Ownership between schools.

It is also worth noting that none of the Thin Client schools studied had only a Thin Client network in place: all had some form of Fat Client network as well.

16.3 School details

Ten schools participated in the submission of Thin Client data to the TCO Tool and nine schools participated in the submission of Fat Client data. While this is not a representative sample for the sector, the sample may give an indication of the trends that could be expected.

The schools' data has been reviewed in two groups: Primary and Secondary.

The high-level school detail from the sample is shown in tables 16.1 and 16.2. These tables provide the context on which the subsequent analysis can be based. As can be seen, even within the relatively broad bands of the analysis breakdown there is a significant variance in the schools in terms of size and budget and expenditure on ICT.

Throughout this section of the report the following headings for tables have been used:

- Thin Client Low – Lowest Thin Client school value for the listed element from the sample
- Thin Client High – Highest Thin Client school value for the listed element from the sample
- Thin Client Average – Average Thin Client school value for the listed element from the sample
- Fat Client Low – Lowest Fat Client school value for the listed element from the sample
- Fat Client High – Highest Fat Client school value for the listed element from the sample
- Fat Client Average – Average Fat Client school value for the listed element from the sample.

The term FTE, referred to in the context of staff, used within the following tables stands for Full Time Equivalent. It is the sum of the parts of a year for which a member of staff works. For example – 0.2 FTE is the equivalence of working 1 day a week. 0.5 would be 2.5 days per week etc.

Table 16.1: characteristics of the primary schools studied

Primary Schools	Thin Client Low	Thin Client High	Thin Client Average	Fat Client Low	Fat Client High	Fat Client Average
Number of Pupils	269	396	341	215	512	330
Total number of permanent staff (excluding long-term absences but including ICT support staff)	28	34	31	21	38	31
Total number of permanent staff FTEs (excluding long-term absences, but including ICT support staff)	23	29	26	19	35	26

Primary Schools	Thin Client Low	Thin Client High	Thin Client Average	Fat Client Low	Fat Client High	Fat Client Average
Pupil to Staff Ratio	7.9	14.1	11.4	5.7	16.7	11.3
Pupil to FTE Staff Ratio	9.4	17.2	13.3	8.2	18.9	13.0

Table 16.2: characteristics of the secondary schools studied

Secondary Schools	Thin Client Low	Thin Client High	Thin Client Average	Fat Client Low	Fat Client High	Fat Client Average
Number of Pupils	915	1,432	1,230	810	1,442	1,092
Total number of permanent staff (excluding long-term absences but including ICT support staff)	73	149	104	79	200	127
Total number of permanent staff FTEs (excluding long-term absences, but including ICT support staff)	72	137	93	75	179	113
Pupil to Staff Ratio	8.2	16.1	12.2	7.2	11.9	9.1
Pupil to FTE Staff Ratio	10.0	19.5	13.8	8.0	12.7	10.1

16.4 Overview of costs

Figure 16.1 shows a summary of different ICT costs as a percentage of the total budget for the each of the categories of school. The indicators are that support and hardware costs are the two most significant single elements of the total spend. Whether the school is Thin or Fat Client, support costs may amount to half the ICT budget.

Figure 16.1 provides an indication that the Thin Client primary schools studied spend a lower proportion of their budget on support than the Fat Client primary schools studied. This factor is marginal for secondary schools but again Figure 16.1 does show a marginal difference.

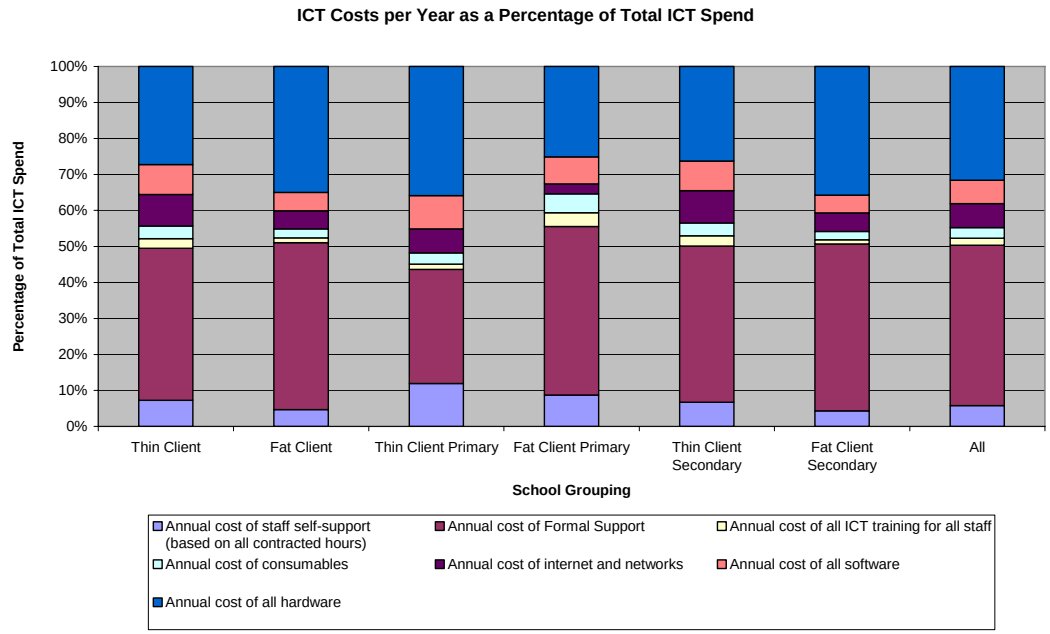

Figure 16.1: ICT Costs per Year as a Percentage of Total ICT Budget

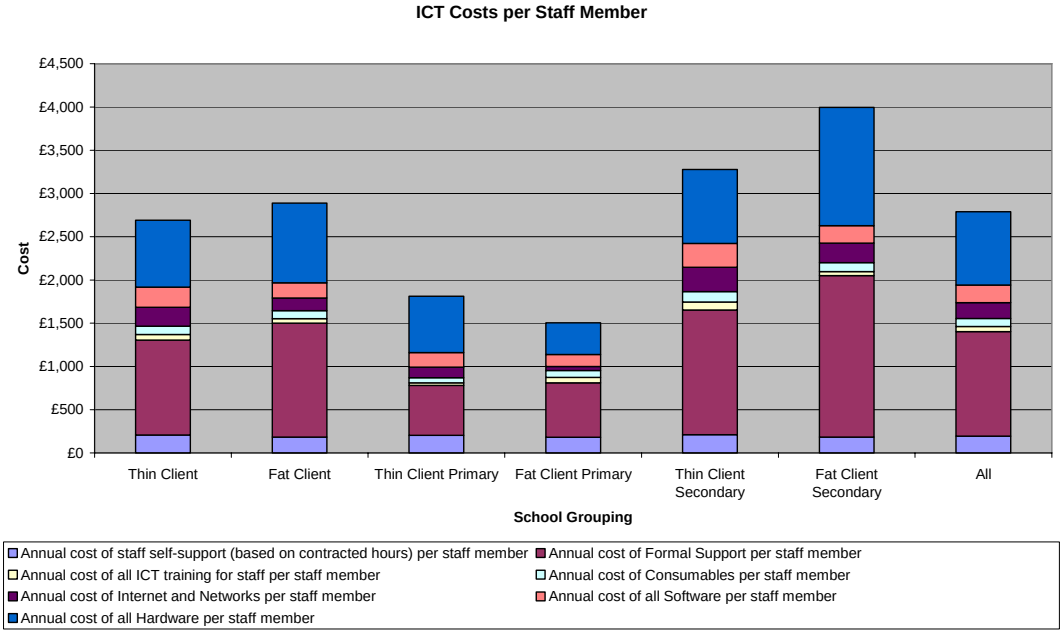

Figure 16.2: ICT Costs per Staff Member

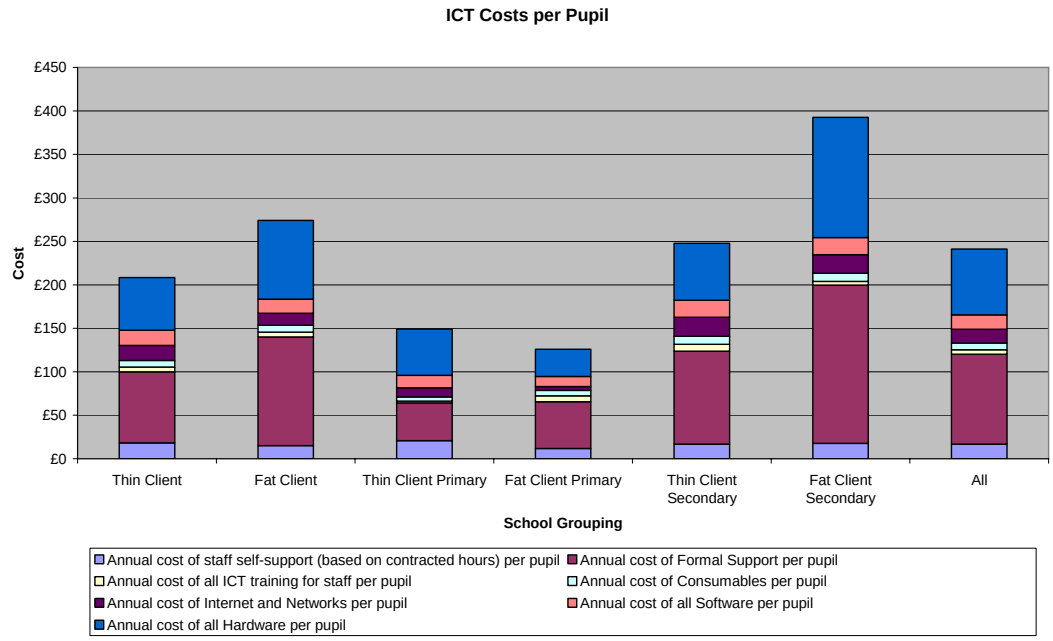

Figure 16.3: ICT Costs per Pupil

The costs per staff member indicate that overall Thin Client costs per staff member are less than for Fat Client in the schools studied. However, the sample size is very small and there was one Fat Client school and two Thin Client schools with significantly higher ICT spend than the others in the sample. It is considered that these results may adversely influence the results.

The costs per pupil indicate a similar trend to the costs per staff member, suggesting, as expected, that these costs and the ratio of staff to pupils is consistent.

Figures 16.2 and 16.3 show that the costs of ICT in the secondary schools studied are two to three times those at the primary schools studied, which may be expected due to the nature and complexity of the provision being delivered in each type of institution.

The figures indicate that for primary schools there are potentially higher total costs for implementing and running a Thin Client network when compared to the Fat Client primary schools studied, whereas adopting a Thin Client network in a secondary school appears the less expensive option on a per capita basis. However, all of Thin Client schools participating in the study had adopted a hybrid approach (Thin and Fat Client), as discussed elsewhere in this report. The figures for the total cost of ownership include both the Thin and Fat Client costs in these schools, so it is difficult to draw detailed conclusions about the total costs for the Thin Client network alone.

The results below confirm that where greater numbers of personal computers are required in a school, there may be economies of scale.

The data suggests that overall Thin Client is cheaper than Fat Client on a unit basis. The trend in Figure 16.2 continues from Figure 16.3 and Figure 16.4, indicating that the school priorities and spend are driving the relative costs in primary schools. Whilst the same may be true of secondary schools studied, they appear more able to generate economies of scale,

resulting in a Total Cost of Ownership per personal computer of nearly 40 per cent less than their Fat Client counterparts in this study.

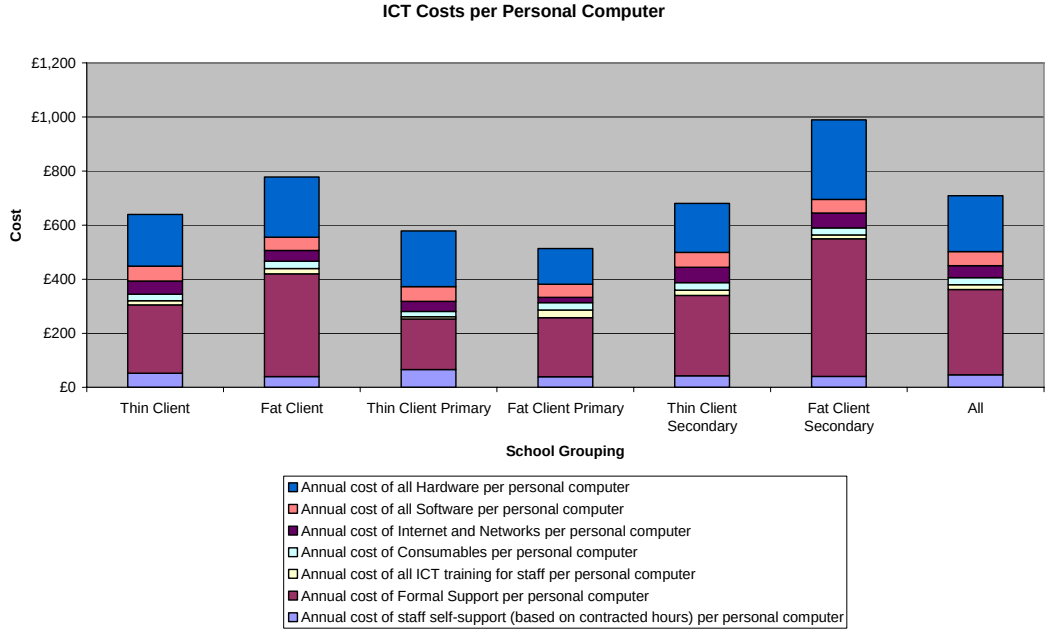

Figure 16.4: ICT Costs per Terminal or Personal Computer

16.5 ICT within the school - Primary

16.5.1 ICT Staff

The following table indicates that within primary schools, those with Thin Client technology have a lower level of formal support than do Fat Client schools. However, this needs to be taken into consideration with formal, informal and contracted support (See Section 16.5.2). On average, Fat Client requires over three times more full-time equivalent staff for formal support than Thin Client, though this finding does not take into account the significant external support that the primary schools had secured. This is a significant factor for primary schools where the availability of such support is often more limited and the overall staffing budget may be more restricted.

Table 16.3: ICT Support in Primary Schools Studied

Primary Schools	Thin Client Low	Thin Client High	Thin Client Average	Fat Client Low	Fat Client High	Fat Client Average
Number of FTEs for formal support	0.00	0.50	0.19	0.00	1.90	0.68
Number of FTEs for formal support per 100 terminal or personal computers	0.00	0.54	0.22	0.00	1.52	0.76

Primary Schools	Thin Client Low	Thin Client High	Thin Client Average	Fat Client Low	Fat Client High	Fat Client Average
Number of FTEs for formal support per 100 pupils	0.00	0.13	0.05	0.00	0.37	0.19

16.5.2 ICT Support

The following graph and table indicate the levels of support for the infrastructure based on whole costs. There is a significant variation in the values that have been submitted by the sample. One of the Fat Client schools shows extremely low support values and one each of the Thin and Fat Client schools shows a significantly higher spend than the others.

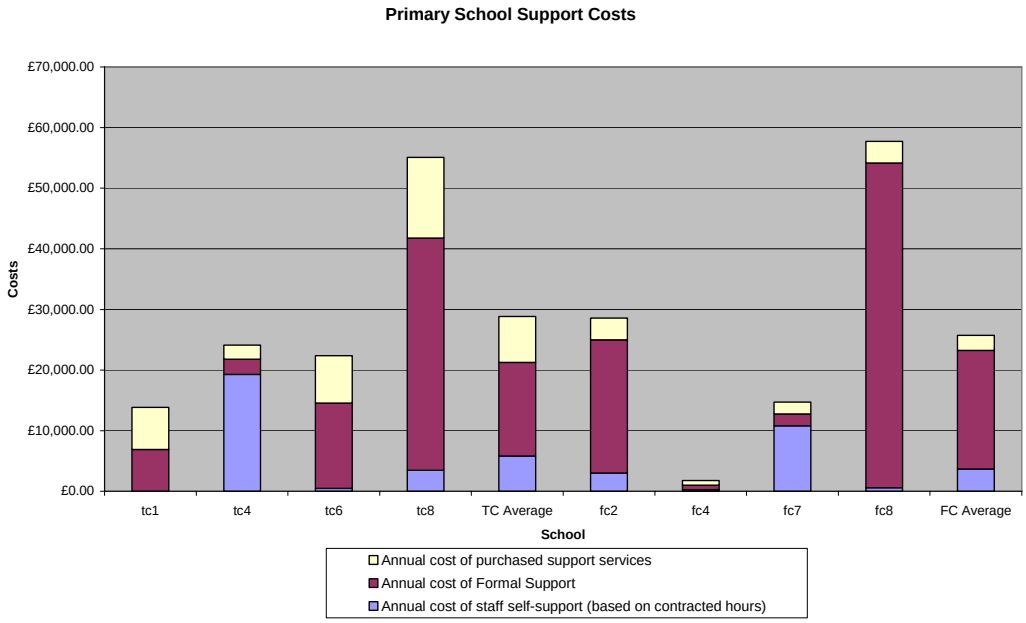

Figure 16.5: Primary School Support Costs

Table 16.4: Primary School Support Costs

Primary Schools	Thin Client Low	Thin Client High	Thin Client Average	Fat Client Low	Fat Client High	Fat Client Average
Annual cost of staff self-support (based on contracted hours)	£0.00	£19,288.11	£5,814.32	£246.76	£10,784.01	£3,651.94
Annual cost of formal support	£2,495.00	£38,300.00	£15,442.46	£770.00	£53,591.35	£19,573.98
Annual cost of purchased support services	£2,345.00	£13,300.00	£7,595.00	£770.00	£3,600.00	£2,485.00

The graph and table below indicate that for the Thin Client schools there is a greater consistency for the costs of supporting the network. Evidently the schools make their own decisions whether to use formal, informal or contracted support, but a level of £300 to £400 per terminal per annum can be expected.

For the Fat Client schools there is a significant variation in costs and based on the sample and the information available it is not possible to draw any specific conclusions.

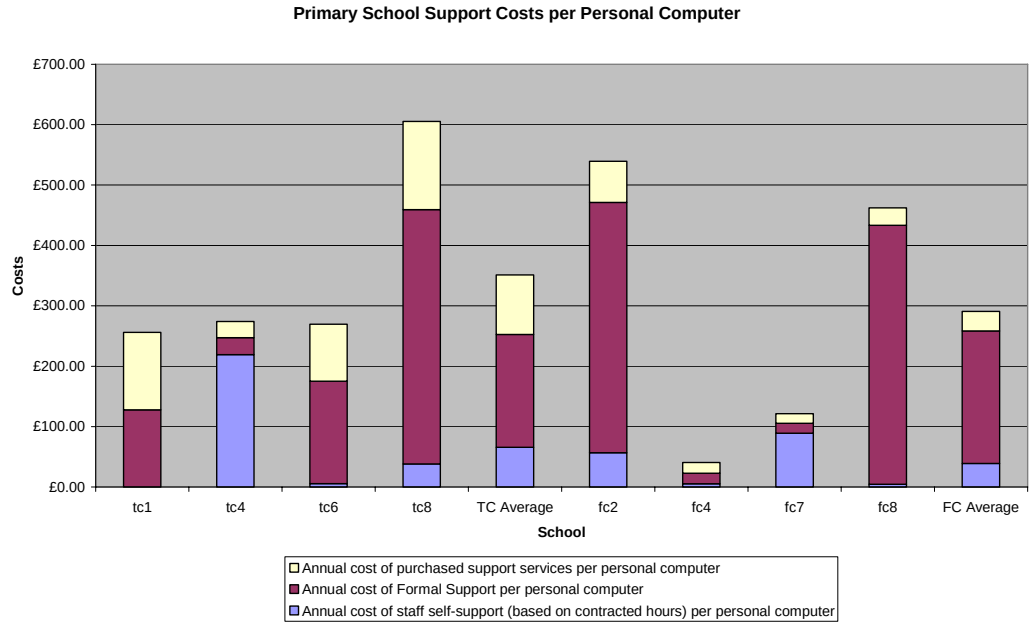

Figure 16.6: Primary School Support Costs per Terminal or Personal Computer

Table 16.5: Primary School Support Costs per Terminal or Personal Computer

Primary Schools	Thin Client Low	Thin Client High	Thin Client Average	Fat Client Low	Fat Client High	Fat Client Average
Annual cost of staff self-support (based on contracted hours) per terminal or personal computer	£0.00	£219.18	£65.83	£4.46	£89.12	£39.03
Annual cost of formal support per terminal or personal computer	£28.35	£420.87	£186.66	£16.28	£428.73	£219.23
Annual cost of purchased support services per terminal or personal computer	£26.64	£146.15	£98.76	£16.28	£67.92	£32.63

Again, the graph and table below provide a similar picture to the Thin Client pattern, in that approximately £80 per annum per pupil would cover the support costs. The variation in the Fat Client schools does not enable any conclusions to be drawn.

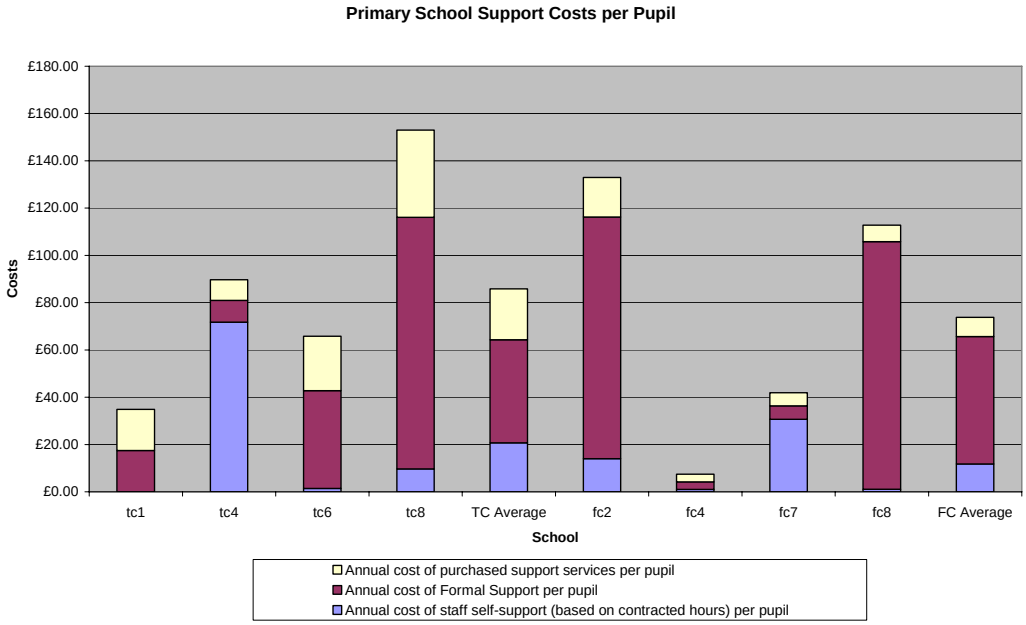

Figure 16.7: Primary School Support Costs per Pupil

Table 16.6: Primary Support Costs per Pupil

Primary Schools	Thin Client Low	Thin Client High	Thin Client Average	Fat Client Low	Fat Client High	Fat Client Average
Annual cost of staff self-support (based on contracted hours) per pupil	£0.00	£71.70	£20.70	£1.02	£30.72	£11.72
Annual cost of formal support per pupil	£9.27	£106.38	£43.61	£3.19	£104.67	£53.91
Annual cost of purchased support services per pupil	£8.71	£36.94	£21.53	£3.19	£16.74	£8.14

16.5.3 ICT Budget

As shown in Figure 16.8, there is significant variation of the annual spend incurred by primary schools within the sample. The variation in spends between the schools does not provide any significant trends, though some conclusions can be drawn by comparing costs against a baseline such as percentage of school budget, costs per personal computer etc (covered below).

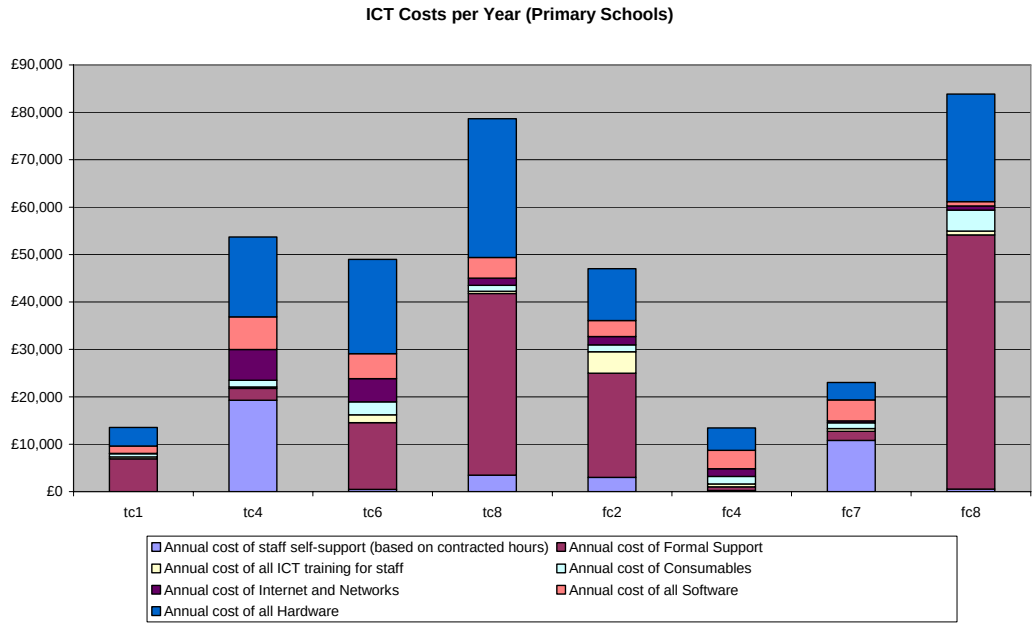

Figure 16.8: ICT Costs per Year (Primary Schools)

Figure 16.9 shows that the Thin Client primary schools are spending a greater percentage of their school budget on ICT than their Fat Client counterparts in this study. A greater sample size would be needed to draw conclusions about overall trends in Thin Client primary schools as opposed to Fat Client ones.

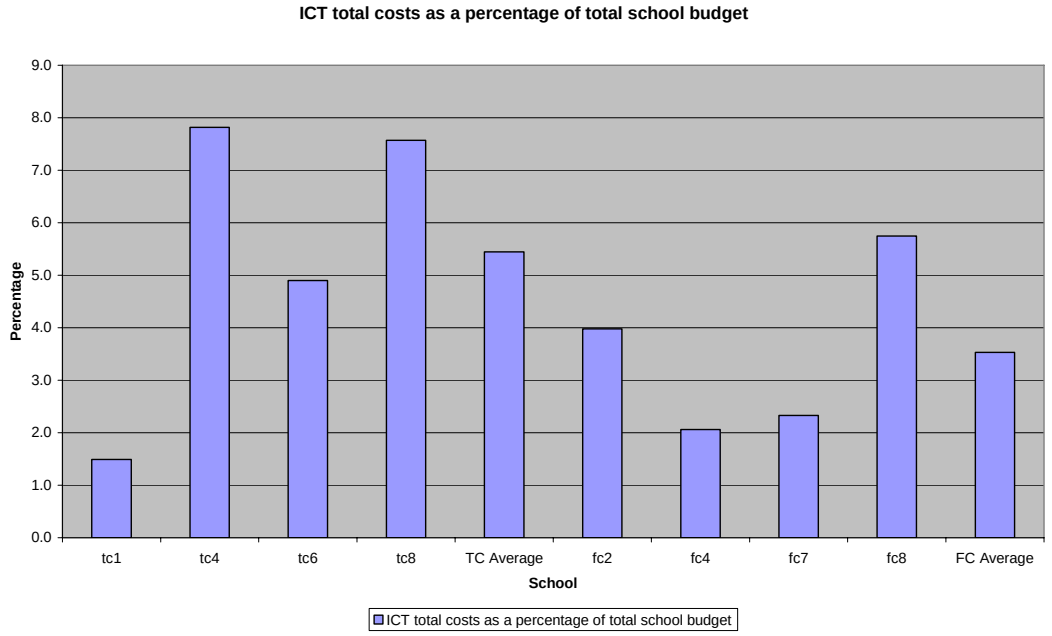

Figure 16.9: ICT Total Costs as a Percentage of Total School Budget

Figure 16.10 continues the trend already shown.

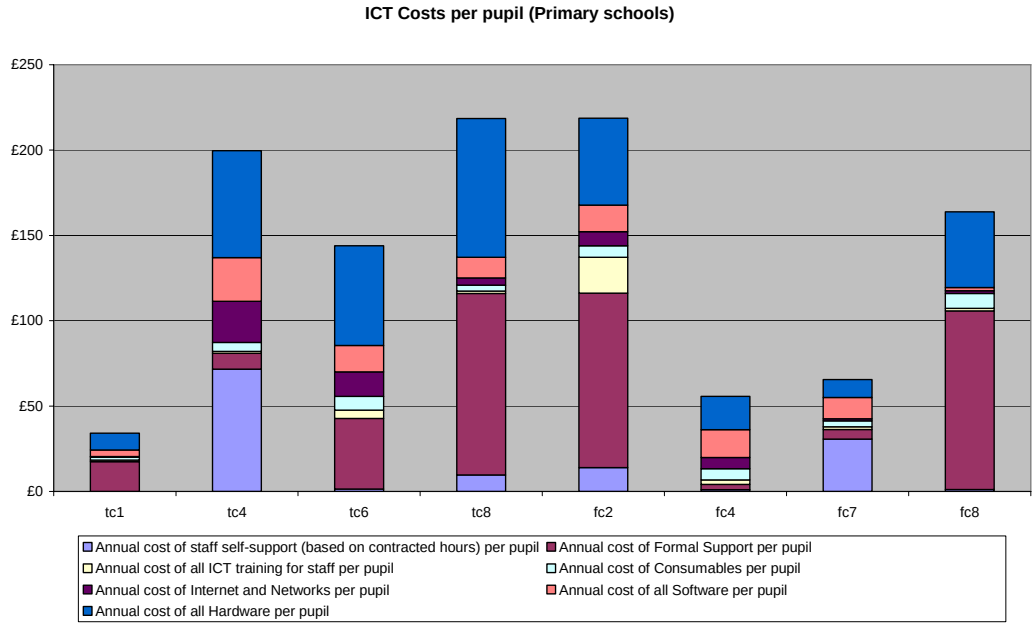

Figure 2.10: ICT Costs per Pupil (Primary Schools)

The following table indicates that costs in the primary schools studied appear to be greater for Thin Client schools. It is not clear why this is the case, though it could be that the spend on establishing the network did not achieve economies of scale due to the smaller number of terminals required, compared to the secondary schools studied. There is also a greater range for ICT total costs as a percentage of the total school budget for Thin Client schools than for Fat Client schools.

Table 16.7: Indicators of Total Costs of ICT in Primary Schools

Primary Schools	Thin Client Low	Thin Client High	Thin Client Average	Fat Client Low	Fat Client High	Fat Client Average
ICT total costs as a percentage of total school budget	1.5%	7.8%	5.4%	2.1%	5.8%	3.5%
The total annual cost of the ICT per staff member	£588	£2,741	£1,808	£569	£2,413	£1,504
The total annual cost of the ICT per pupil	£34	£218	£149	£56	£219	£126

16.5.4 Hardware

Thin Client schools have a greater range for the annual costs for hardware per pupil than do Fat Client schools. The lowest values are the same but within the sample the greatest spend was in a Thin Client school. Reference to Section 16.6.3 will show that this is the opposite of the case for secondary schools. As Figure 16.11 shows, the range in annual costs per PC also varies considerably between Thin Client schools, though the variation is less than for Fat Client schools.

It was expected that the data collection would show that schools' expenditure on computers/terminals would be less per personal computer for Thin Client than Fat Client. However, the figures for primary schools indicate the reverse. The TCO Tool only covers costs incurred over the last three years and any equipment purchased before that period would not be fully covered.

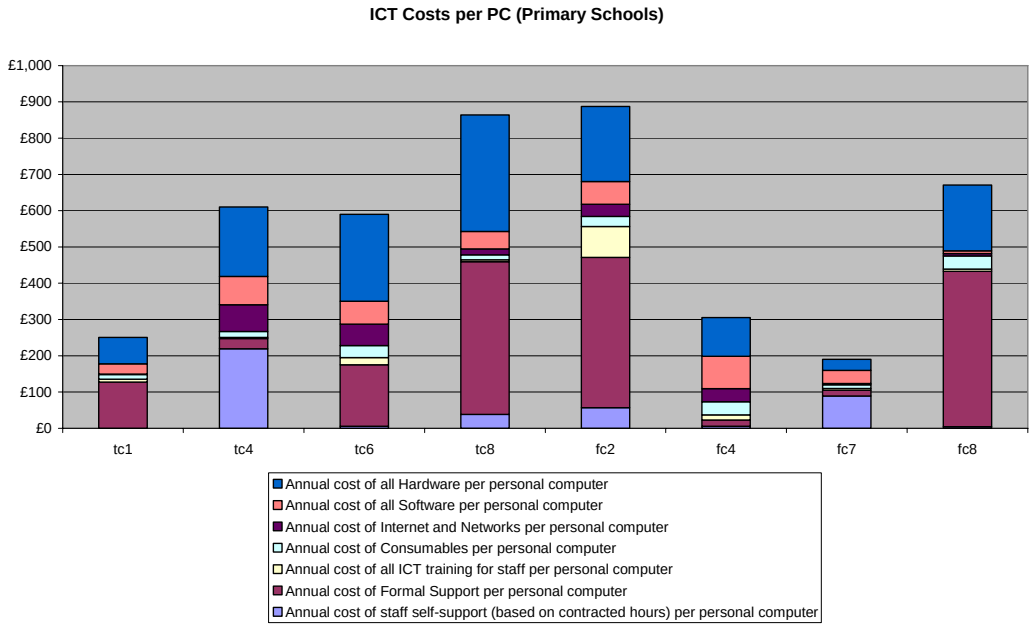

Figure 16.11: ICT Costs per PC in Primary Schools Studied

Table 16.8: Hardware Costs per Pupil in Primary Schools Studied

Primary Schools	Thin Client Low	Thin Client High	Thin Client Average	Fat Client Low	Fat Client High	Fat Client Average
Annual cost of all hardware per pupil	£10	£81	£53	£10	£51	£31

16.5.5 ICT Terminals and Printers

The data below illustrates that the numbers of pupils per client (that is, terminal in Thin Client schools or personal computer in Fat Client schools) is slightly higher in Thin Client primary schools than Fat Client, with the reverse being true in secondary schools.

The number of pupils per printer/plotter is much higher in Thin Client schools. Though one school has a significantly higher ratio here, the trend is still higher in Thin Client schools rather than Fat Client schools.

The number of clients per server is less in Thin Client schools, as is the average age of the clients.

Table 16.9 – Hardware Provision in Primary Schools Studied

Primary Schools	Thin Client Low	Thin Client High	Thin Client Average	Fat Client Low	Fat Client High	Fat Client Average
Total number of personal computers (excl. PDAs)	54	91	79	44	125	86
Number of students per personal computer (incl. PDAs)	3.1	7.3	4.6	2.9	5.5	4.1
Number of students per printer / plotter	44.8	132.0	78.9	20.1	35.8	29.9
Number of personal computers (incl. PDAs) per server	22.0	45.5	30.5	8.8	121.0	53.9
Number of personal computers (incl. PDAs) per printer / plotter	11.9	22.8	16.8	3.7	12.1	7.9
Average age of personal computers (incl. PDAs)	2.6 yrs	3.8 yrs	3.0 yrs	3.1 yrs	3.7 yrs	3.4 yrs

16.5.6 Applications

Costs for application software are higher across all measures for Thin Client than Fat Client. Significantly, the cost of educational software is twice as high for Thin Client than for Fat Client. It was suggested by the schools that software that is compatible for Thin Client is not as readily available as that for Fat Client. The smaller market and fewer competitors might explain why unit costs are higher.

The numbers of applications declared through the TCO Tool appear to be inconsistent. As a consequence, the figures for overall costs have been analysed here. This suggests that these figures should be treated with caution – as explained above, they have not been checked for accuracy.

Table 16.10 – Software Costs in Primary Schools Studied

Primary Schools	Thin Client Low	Thin Client High	Thin Client Average	Fat Client Low	Fat Client High	Fat Client Average
Annual cost of all Software	£1,517	£6,865	£4498	£918	£4,409	£3,146
Annual cost of office applications	£0	£352	£161	£0	£277	£73
Annual cost of admin application software	£0	£1,610	£425	£0	£1,233	£308
Annual cost of educational software	£1,476	£4,608	£3,569	£0	£3,537	£1,738

16.5.7 Training

The data shows that for all aspects of training except ICT training for administration, the annual costs for Thin Client schools are less than for Fat Client schools. Significantly, the amount spent on staff training for Thin Client schools was half that of Fat Client schools and the annual cost of educational ICT training was only 15 per cent of that spent by Fat Client schools. For both Thin and Fat Client schools, some schools spent nothing on training for administration ICT.

Table 16.11 – Training Costs in Primary Schools

Primary Schools	Thin Client Low	Thin Client High	Thin Client Average	Fat Client Low	Fat Client High	Fat Client Average
Annual cost of all ICT training for staff	£300	£1,650	£713	£570	£4,500	£1,618
Annual cost of educational ICT training for staff	£0	£500	£125	£80	£2,300	£790
Annual cost of admin ICT training for staff	£0	£1,650	£550	£0	£700	£328
Annual cost of management ICT training for staff	£0	£150	£38	£0	£1,500	£500

16.6 ICT within the school - Secondary

16.6.1 ICT support

The following table indicates that within secondary schools, Thin Client schools employ fewer support staff per pupil and per computer. However, this needs to be considered alongside informal and contracted support (See Section 10.5.2 oops – there isn't one 10.3.3 perhaps?).

Table 16.12 – ICT Support Staff in Secondary Schools Studied

Secondary Schools	Thin Client Low	Thin Client High	Thin Client Average	Fat Client Low	Fat Client High	Fat Client Average
Number of FTEs for formal support	2.00	7.46	4.57	2.00	12.00	7.48
Number of FTEs for formal support per 100 personal computers	0.47	1.70	1.07	0.58	3.32	1.91
Number of FTEs for formal support per 100 pupils	0.19	0.52	0.36	0.21	1.09	0.70

The following graph and table indicate the levels of support for the infrastructure based on total costs. There is a significant variation in the values that have been submitted by the sample. Given the diversity of the sample, based on the information below, it is not possible to provide any conclusions.

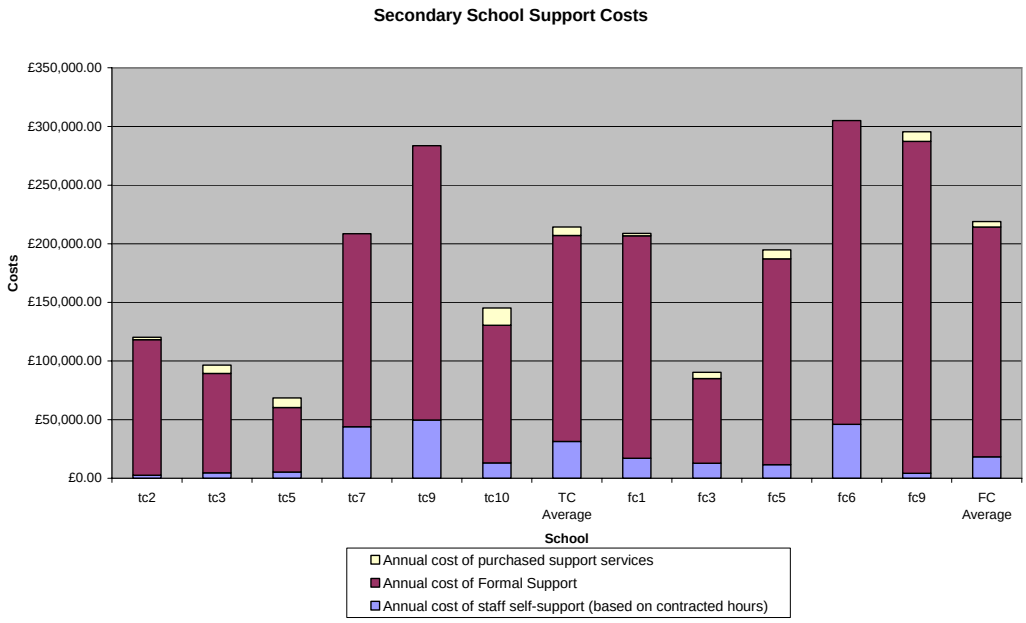

Figure 16.12: Comparison of Secondary School Support Costs

Table 16.13: Annual Support Costs in Secondary Schools Studied

Secondary Schools	Thin Client Low	Thin Client High	Thin Client Average	Fat Client Low	Fat Client High	Fat Client Average
Annual cost of staff self-support (based on contracted hours)	£2,730.55	£49,689.64	£15,130.34	£4,257.15	£46,058.67	£18,396.31
Annual cost of formal support	£55,090.00	£233,883.37	£121,300.66	£72,250.00	£282,991.06	£195,823.54
Annual cost of purchased support services	£0.00	£14,590.00	£6,356.00	£0.00	£8,300.00	£4,688.00

The graph and table below indicate that there is a greater consistency for the costs of supporting the network. Evidently the schools make their own decisions whether to use formal, informal or contracted support, but a level of £300 to £400 per terminal per annum can be expected, as with the primary schools in this study. Thin Client schools in some cases tend to make greater use of contracted support.

For the Fat Client Schools there is still a significant variation in costs, but the trend (despite the two high spending schools) indicates a greater support requirement of Fat Client schools.

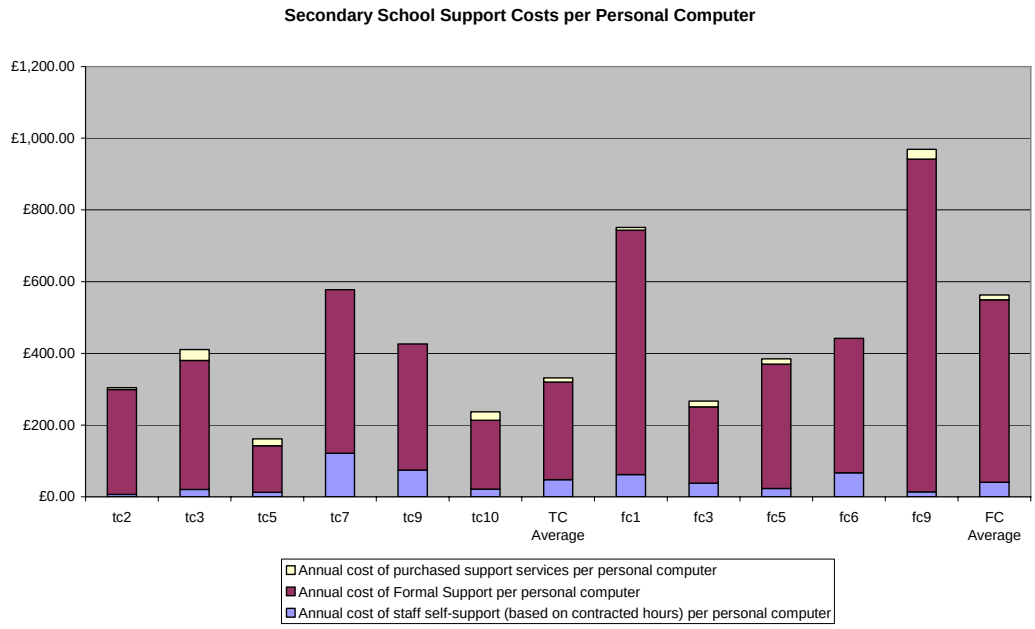

Figure 16.3: Secondary School Support Costs per Personal Computer

Table 16.14: Support Costs in Secondary Schools per terminal or Personal Computer

Secondary Schools	Thin Client Low	Thin Client High	Thin Client Average	Fat Client Low	Fat Client High	Fat Client Average
Annual cost of staff self-support (based on contracted hours) per terminal or personal computer	£6.91	£121.60	£27.18	£13.95	£66.75	£40.68
Annual cost of formal support per terminal or personal computer	£129.92	£455.84	£265.23	£213.12	£681.65	£508.91
Annual cost of purchased support services per terminal or personal computer	£0.00	£29.78	£15.60	£0.00	£27.21	£13.16

Again the graph and table below provide a similar picture to the Thin Client pattern, in that approximately £150 would cover the annual support costs per pupil in a Thin Client school whereas the cost in a Fat Client school would be £200 per pupil per year. In terms of support costs per PC or terminal, Thin Client secondary schools are on average cheaper, with formal support being nearly half that of Fat Client schools on average (£265 per PC in Thin Client schools compared to £508 in Fat Client schools). These figures suggest that secondary school costs are approximately twice those for a primary school, which might be explained by greater budgets for ICT in the secondary school sector, compared to the primary sector.

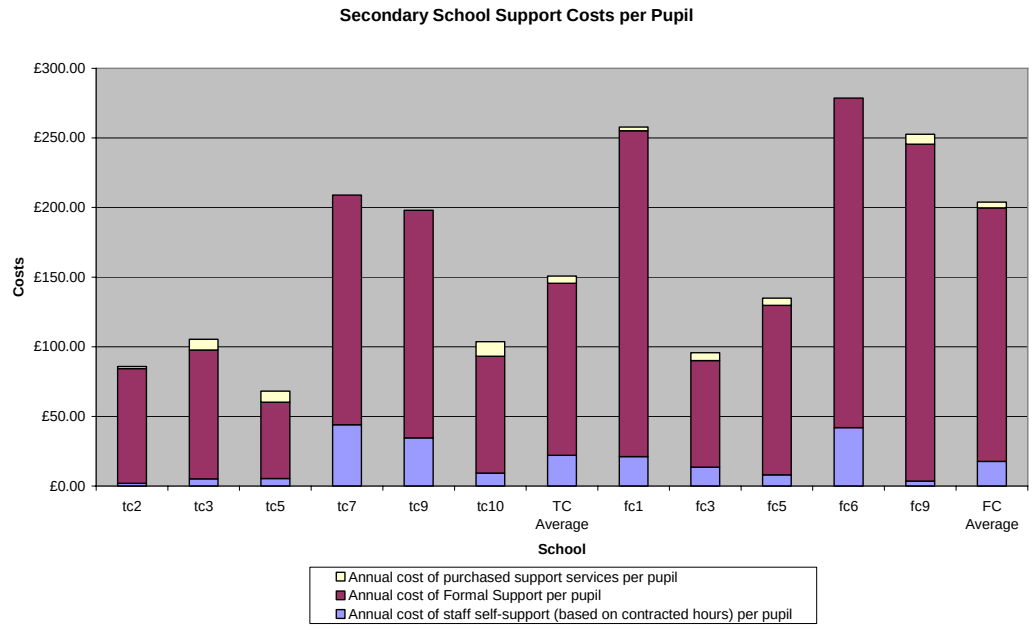

Figure 16.14: Secondary School Support Costs per Pupil

Table 16.15: Support Costs per Pupil in Secondary Schools Studied

Secondary Schools	Thin Client Low	Thin Client High	Thin Client Average	Fat Client Low	Fat Client High	Fat Client Average
Annual cost of staff self-support (based on contracted hours) per pupil	£1.94	£43.98	£11.30	£8.07	£42.06	£17.71
Annual cost of formal support per pupil	£82.40	£164.88	£95.40	£76.53	£241.87	£182.10
Annual cost of purchased support services per pupil	£0.00	£10.42	£5.52	£0.00	£7.09	£4.14

16.6.2 ICT Budget

The detail below indicates that at the secondary level the cost of Fat Client provision appears, on average, to be greater than for Thin Client provision. The range of the budget spent on ICT as a percentage of the total school budget is bigger for Fat Client schools than for Thin Client. It is also apparent that more is being spent per staff member and per pupil in Fat Client schools than in Thin Client schools.

If the figures for Fat Client 6 (fc6) are disregarded, there is a greater level of consistency. However, though Fat Client 1 (fc1) has had a similar ICT Budget to Total School Budget ratio, its unit costs per pupil are not significantly different from the remainder of the sample.

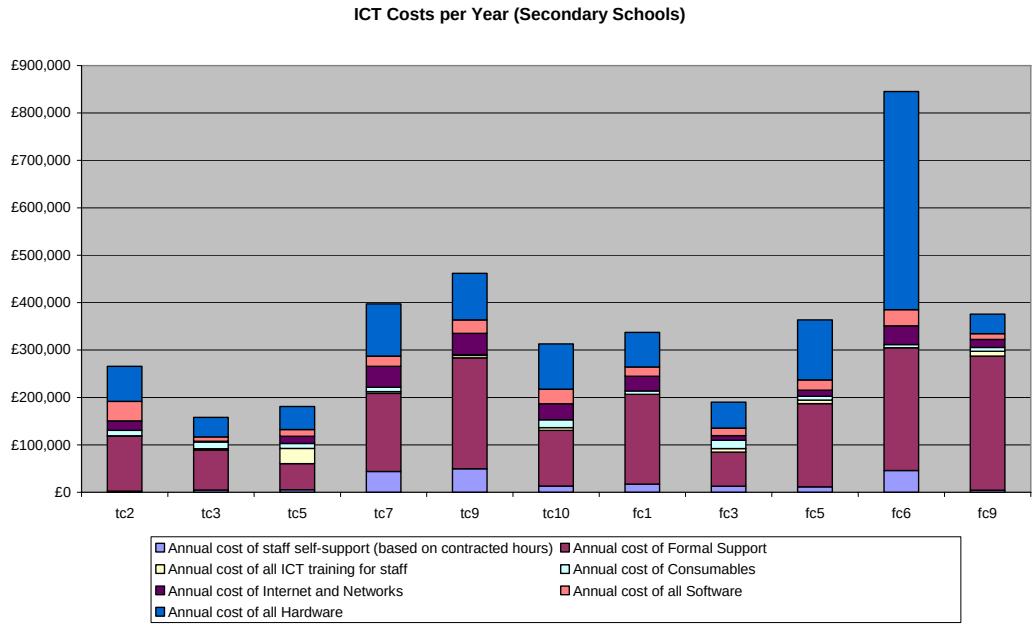

Figure 16.15: ICT Costs per Year (Secondary Schools)

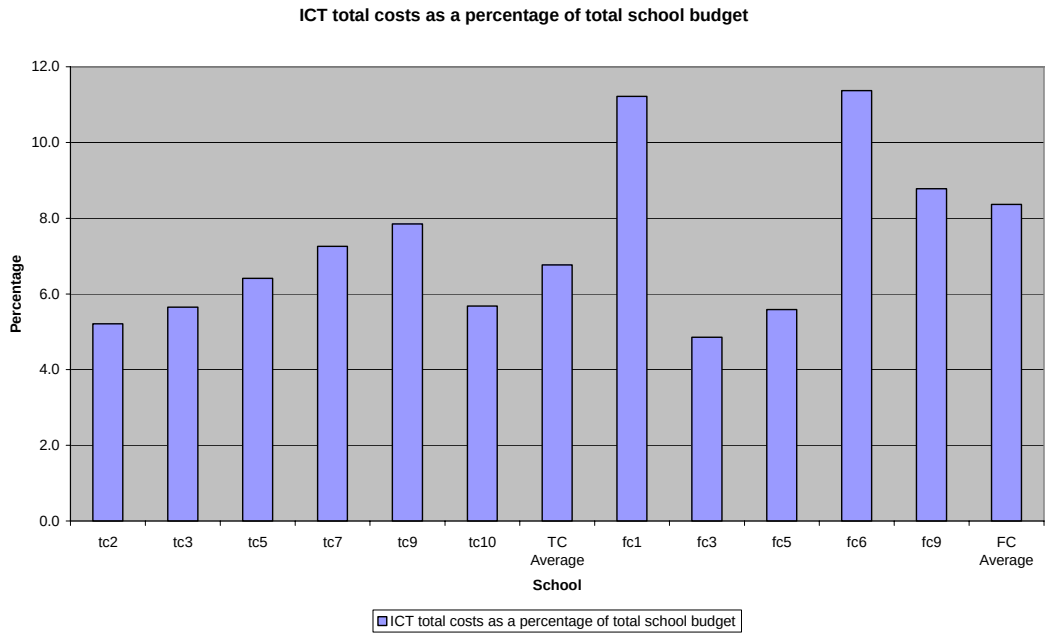

Figure 16.16: ICT Total Costs as a Percentage of Total School Budget

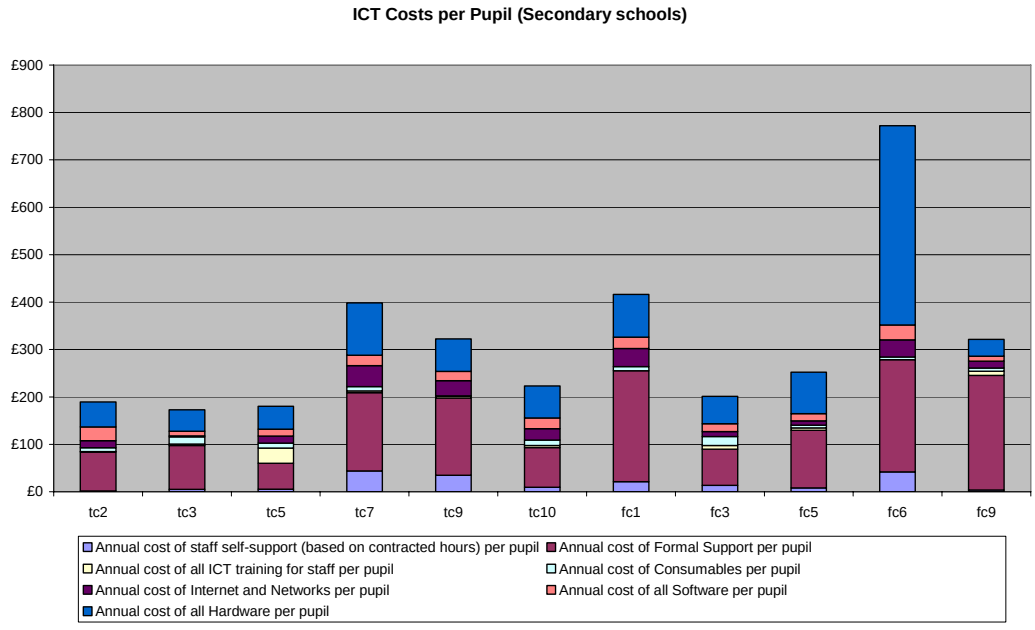

Figure 16.4: ICT Costs per Pupil (Secondary Schools)

Table 16.16: Indicators of Total Costs of ICT in Secondary Schools Studied

Secondary Schools	Thin Client Low	Thin Client High	Thin Client Average	Fat Client Low	Fat Client High	Fat Client Average
ICT total costs as a percentage of total school budget	5.2%	7.9%	6.2%	4.9%	11.4%	8.4%
The total annual cost of the ICT per staff member	£1,987	£4,886	£3,032	£2,035	£7,297	£3,965
The total annual cost of the ICT per pupil	£171	£378	£211	£198	£771	£390

16.6.3 Hardware

Unlike primary schools, the annual expenditure on hardware per pupil and per PC is significantly less for Thin Client secondary schools than Fat Client secondary schools studied, being 41 per cent of the amount spent in Fat Client secondary schools studied. Consequently, it is believed that given the evidence from the TCO results, there are economies in purchasing Thin Client technology and that secondary schools with their greater requirement for numbers of personal computers may obtain some economy of scale.

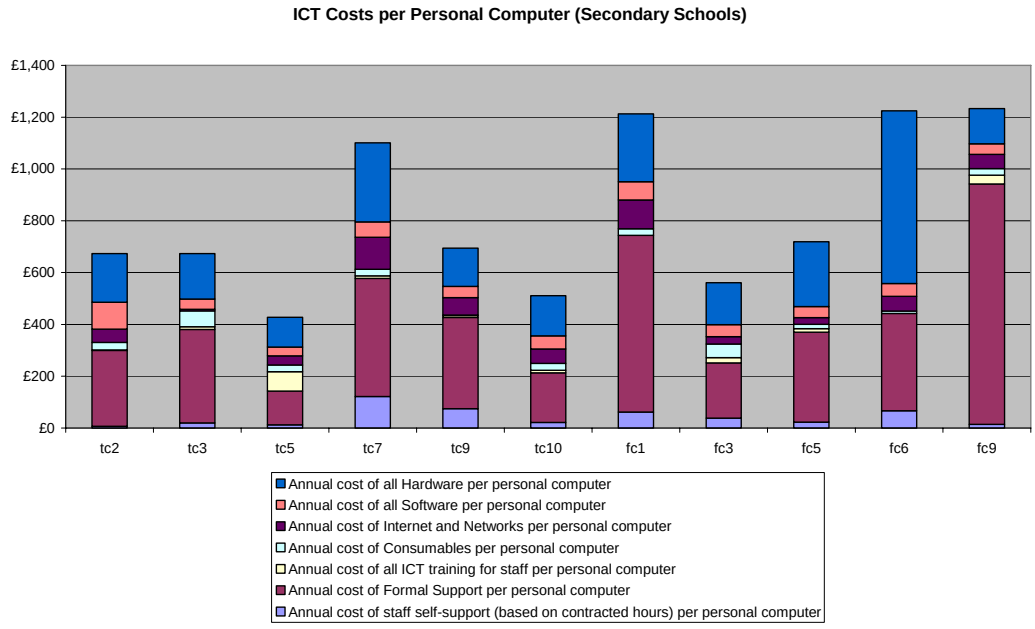

Figure 16.5: ICT Costs per Personal Computer (Secondary Schools)

Table 16.17: Annual Cost of Hardware per Pupil in Secondary Schools Studied

Secondary Schools	Thin Client Low	Thin Client High	Thin Client Average	Fat Client Low	Fat Client High	Fat Client Average
Annual cost of all hardware per pupil	£45	£110	£57	£35	£420	£138

16.6.4 ICT Terminals and Printers

Thin Client secondary schools had on average slightly more personal computers than Fat Client secondary schools, although the average number of students per terminal or personal computer is the same. The data suggests that there is a 'standard' ratio of pupils to personal computers and that the requirement in the Thin Client secondary schools was higher than for Fat Client secondary schools. There are fewer computers per server in Thin Client secondary schools, suggesting that though the servers are supporting more personal computers, the servers are of a higher specification. The numbers of pupils and personal computers per printer/plotter is significantly higher in Thin Client schools.

Table 16.18: Hardware Provision in Secondary Schools Studied

Secondary Schools	Thin Client Low	Thin Client High	Thin Client Average	Fat Client Low	Fat Client High	Fat Client Average
Total number of personal computers (excl. PDAs)	235	665	466	278	690	424
Number of students per personal computer (incl. PDAs)	2.1	3.9	2.8	1.6	3.8	2.8
Number of students per printer / plotter	17.8	155.7	52.5	13.7	20.1	17.2
Number of personal computers (incl. PDAs) per server	13.8	55.3	29.8	26.0	99.4	62.7
Number of personal computers (incl. PDAs) per printer / plotter	6.9	44.4	17.3	5.3	8.7	6.5
Average age of personal computers (incl. PDAs)	2.6 yrs	3.2 yrs	3.0 yrs	2.5 yrs	3.1 yrs	2.8 yrs

16.6.5 Applications

As with primary schools, the Thin Client secondary schools studied are spending more on software than Fat Client schools by an average of about £4,000 per year. Nearly twice as much is spent on software for administration applications in Thin Client schools. Spending on educational software is less in the Thin Client secondary schools studied, but only by £439 on average out of a total annual spend of around £9,000.

It was suggested by the schools that software that is compatible for Thin Client technology is not as readily available as that for Fat Client. The smaller market and fewer competitors may explain the higher costs, as may licensing arrangements (Thin Client schools may be more likely to have site licences than Fat Client schools).

The numbers of applications declared through the TCO Tool appear to be inconsistent. As a consequence the figures for overall costs have been analysed here. This suggests that these figures should be treated with caution – as explained above, they have not been checked for accuracy.

Table 16.19 – Software Costs in Secondary Schools Studied

Secondary Schools	Thin Client Low	Thin Client High	Thin Client Average	Fat Client Low	Fat Client High	Fat Client Average
Annual cost of all software	£9,183	£40,967	£24,753	£12,292	£34,340	£20,689
Annual cost of office applications	£0	£6,667	£2,611	£0	£9,000	£2,187
Annual cost of admin application software	£0	£22,667	£5,467	£0	£6,300	£2,334
Annual cost of educational software	£4,550	£16,000	£8,710	£5,723	£11,330	£9,149

16.6.6 Training

It can be seen that the annual cost of all ICT training for staff is almost twice as much in the Thin Client secondary schools studied than their Fat Client counterparts. This is opposite to the case for primary schools. Further research comparing training practices in schools would be needed to clarify why this should be the case.

In all categories except management training much more is spent on training in Thin Client schools than Fat Client.

Table 16.20: Training Costs in Secondary Schools Studied

Secondary Schools	Thin Client Low	Thin Client High	Thin Client Average	Fat Client Low	Fat Client High	Fat Client Average
Annual cost of all ICT training for staff	£1,000	£32,000	£9,368	£0	£10,450	£4,931
Annual cost of educational ICT training for staff	£1,000	£18,000	£5,340	£0	£4,250	£1,578
Annual cost of admin ICT training for staff	£0	£14,000	£3,940	£0	£2,541	£748
Annual cost of management ICT training for staff	£0	£1,305	£88	£0	£5,000	£2,605

16.7 Observations

Based on the analysis of the TCO data, the following observations have been made:

- The Total ICT costs per staff member (excluding the hardware element) are very similar for primary schools and marginally less expensive in secondary schools between Thin and Fat Client. However, if hardware costs are included, Thin Client becomes more expensive for primary schools but less expensive for secondary schools.
- The support requirement in terms of cost is less for a Thin Client network in primary schools, perhaps because outsourced support is cheaper than providing that support in-house.
- In secondary schools, as a percentage of the Total ICT spend, the proportion taken by hardware in Thin Client schools is about 10 per cent less than that in Fat Client schools, However, this trend is reversed in primary schools.

17 Appendix 2 - 12 case studies

17.1 School 1

Overview

School 1 is a co-educational primary school. It has 380 pupils on roll and 16 teachers. It is a popular school located in a relatively advantaged area.

The school uses a Thin Client network for its computer suite and to connect one Thin Client terminal in each classroom. Fat Client computers are used to run the interactive whiteboards in the school, and to connect to the Local Authority's management information system.

Further details are set out in the table below.

Size of school	380 pupils, 16 teachers
Thin Client terminals	37 Thin Clients, of which:
Bespoke Thin Client terminals	35
Legacy computers used as Thin Clients	2
Other desktop computers and laptops used as Thin Clients	0
Bespoke Thin Client terminals as percentage of total Thin Client terminals	95%
Fat Client computers	17
Network details	
Age of Thin Client network	Approximately 8 years
Number of servers	A single Windows 2003 server and a RISC OS server delivering legacy applications
Network specification	All devices are connected to the network at 100Mbps
Hybrid / pure Thin Client	Hybrid (majority Thin Client)
System used for school administration	Fat Client
Average number of Thin Client terminals per server	19
Operating system	Windows 2003 / RISC OS and Citrix

Reasons for implementing a Thin Client network

The school wished to continue to use its existing Acorn software, and migrate over time to Windows software. It also wished to contain costs. Having considered various options, the Thin Client network was thought to be the best option.

Teaching and learning benefits and issues

Those interviewed thought that using Thin Client technology had increased confidence in teaching lessons using ICT. The system has a common desktop and the teachers know that what they are seeing is being seen by the whole class. All terminals boot up in the same way and lessons can start 'smartly'.

Those interviewed were aware of the multimedia limitations of using Thin Client but thought that it did not create a major difficulty with teaching. The school has interactive whiteboards which are run off the teacher's laptop which is connected to the network.

Pupils cannot bring in work from home on disk, as there are no disk drives on the Thin Client machines. However, they can either email work in or bring it in on memory stick if they need to. These arrangements make it harder for viruses to be introduced by pupils uploading work.

Technical support
The system is supported and maintained by the third-party network provider. The provider has remote access to the systems to undertake remote diagnostics and perform remote fixes where possible.

Some administration is undertaken in-house.

Lessons learned
The key technology lessons learned and benefits gained from this deployment are as follows.

- The ease of management has enabled the ICT lead to focus on teaching and not on the provision of technology.
- The ease of use and reliability has created confidence within the staff, specifically those without ICT experience, to use the systems for wider curriculum delivery.
- Running costs are low.

17.2 School 2

Overview

School 2 is a co-educational primary school. There are 14 teachers (10.5 full time equivalent) and 270 pupils on roll. The school serves a challenging catchment area on the outskirts of a large town.

The school has implemented a hybrid network using Thin Client as a mechanism for delivering ICT access for students as part of curriculum delivery, whilst enabling teachers to have access to Thin and Fat clients via dual-boot computers to support peripherals and multimedia applications.

Size of school	270 pupils, 14 teachers
Thin Client terminals	80
Bespoke Thin Client terminals	27
Legacy computers used as Thin Clients	3
Other desktop computers and laptops used as Thin Clients	50
Bespoke Thin Client terminals as percentage of total Thin Client terminals	34%
Fat Client computers	58 (50 are the same as above – dual boot machines)
Network details	
Age of Thin Client network	4 years
Number of servers	4 servers
Network specification	10/100mb fast Ethernet throughout
Hybrid / pure Thin Client	Hybrid
System used for school administration	Fat Client
Average number of Thin Client terminals per server	20
Operating system	Windows 2003

Reasons for implementing a Thin Client network

The school had to meet two challenges.

- To extend the availability of ICT to the students beyond the previous provision of two PCs per classroom.
- To provide an environment that was consistent and reliable that would give teachers the confidence to use ICT in lessons, where previously the technology had been perceived as a barrier.

The Thin Client network was found to be the best way of meeting these challenges.

Teaching and learning benefits and issues

All staff have timetabled sessions for their classes in the ICT suite and since establishing the Thin Client network, the incorporation of ICT into lessons has increased markedly. This is due to greater access and more machines. Those interviewed thought that due to the use of a wide range of different media made available through greater access to ICT, lessons had

become more interesting and the children were more motivated. The school decided to have some PCs so that peripherals can be used.

One problem that has been identified with the Thin Client network is that any software that is video rich needs too much bandwidth so cannot be used on Thin Client.

The school also decided to have some PCs so that peripherals and multimedia can be used.

Technical support
The service provider provides onsite support once per week as part of a planned maintenance program. The service provider also addresses any technical issues at that stage and assists with the deployment of new applications.

Lessons learned
- The ratio of pupils to terminals (3.5:1) has been enabled by the low cost of expansion.
- The use of a skilled third party, and the establishment of a good working relationship with that third party, was a major contribution to the success of the deployment.
- The head of ICT found that the availability of advice from other experts and the shared experience with other users was invaluable in assessing the technologies suitability for the school.

17.3 School 3

Overview

School 3 is a junior school with 335 pupils on roll and 14 teachers (14 FTE). The school's vision for ICT is to move from being 'at the cutting edge to the next level, but through evolution, not revolution' (headteacher).

This school operates a hybrid network of approximately 31 Thin Clients and 22 PCs including a small administration network. The school also has around 15 stand-alone laptops and desktop Fat Client PCs. The decision to deploy Thin Client technology was taken for educational and financial reasons which included cost of maintenance, training and management.

The school also needed to be able to extend its ICT deployment to deliver the curriculum at the lowest possible cost. The Thin Client network delivers some curriculum-based software but some is not compatible with the Citrix-based Thin Client network. This is the reason for having a hybrid system.

The option selected was to adopt a Thin Client network. In this instance, the school selected Windows 2003 Enterprise Edition as a Thin Client server technology.

A summary of these details is set out in the following table.

Size of school	335 pupils; 14 teachers (including head)
Thin Client Terminals	31
Bespoke Thin Client terminals	31
Legacy computers used as Thin Clients	0
Other desktop computers and laptops used as Thin Clients	0
Bespoke Thin Client terminals as percentage of total Thin Client terminals	100%
Fat Client computers	22 networked PCs and 15 other laptops/PCs
Network details	
Age of Thin Client network	7 years
Number of servers	3
Network specification	Ethernet local area network
Hybrid / pure Thin Client	Hybrid
System used for school administration	Fat Client for central administration
Average number of Thin Client terminals per server	10 (though the 3 servers perform different functions)
Operating system	Windows Server 2000 Enterprise Edition

Reasons for implementing a Thin Client network

The school chose to implement a Thin Client solution for the following reasons:

- The school had only one or two computers (Acorns) in each classroom. They wanted to install an ICT suite and increase access across the school but still be able to run the Acorn software so that it would be a smooth transition for the staff.

- Cost needed to be kept down, whilst increasing resources across the school.
- Reliability was an important factor.

Teaching and learning benefits and issues
Those interviewed reported the following benefits:

- The reliability of the network and terminals has been a major benefit to the school, producing a very positive attitude towards Thin Client technology.
- The network supports the teaching of ICT itself because much of the software relevant to the ICT curriculum is available on the network and does not need individual teachers' time in maintaining it.
- It has had a big impact on the subject ICT; the attainment levels in ICT are now above the national average and very high compared to other schools in the Local Authority.
- Another benefit, which is due to the reliability and accessibility of the network, is that teachers can now share resources with each other and access other curriculum resources over the internet.
- ''Difficult' boys became stars because they enjoy that type of learning.'
- The Thin Client network has allowed the pupils to work differently according to their individual preferences because they now have enough machines to enable them regular access and they all have an easy-to-use interface.

The following issues were reported:

- Software for numeracy and literacy cannot run properly on the network, although it is possible to run more software on the newer machines. The Advanced skills co-ordinator reported that: 'As a purchaser of software it is more frustrating because many products the school want to use won't run on the network. [We] got £7500 for purchasing software but it was difficult because so many suppliers are not interested in supporting their software to run on Thin Clients.'
- Some software providers are very unhelpful in getting their products to work on Thin Clients. This especially applies to the use of some measurement and control software.
- Multimedia applications do not run efficiently on older terminals, though the school found that this was less of a problem on more recently purchased terminals.
-
- Some of the very young pupils have difficulty logging on because of reading difficulties.

Those interviewed asked for more collaboration between software houses and Thin Client suppliers to ensure that powerful educational software can run on Thin Client networks.

Technical support
The school has an ICT co-ordinator and a full-time technician/librarian who provide the day-to-day support for all the PCs, laptops and interactive whiteboards.

The school has a support contract with the supplier who provides all the system and upgrade support.

Lessons learned

The school is working on a creative curriculum for individual pupils to enable them to make lots of choices. This has influenced their educational software requirements. It would be easier if there was only one network but some software the school wants to use is not compatible with the Thin Client network and terminals (though this was not found to be less of a problem on newer terminals). For example, the school had to purchase Fat Client machines to run some of the software used by Year 6.

Staff interviewed suggested the following lessons for other schools considering Thin Client systems:

- There must be good reasons for embarking on an ICT expansion and clear specifications in order to avoid costly mistakes.
- Schools need to choose a company with a proven record of implementing and supporting Thin Client networks in schools.
- It is important to visit other schools that are already using the technology to see what can be done and also to look at the Total Cost of Ownership and budget demands.
- Schools should find opportunities to familiarise themselves with the system and the software which will run on it before choosing the final system.
- A hybrid system provides the best coverage of ICT for teaching it as a subject and across the curriculum.
- Having USB slots at the front of the newer terminals has changed the way things can be accessed, but those interviewed reported that some software providers are very unhelpful in getting their products to work on Thin Clients. This especially applies to the use of some measurement and control software.
- A phased programme of implementation is helpful to the teachers, consolidating as the school progresses.
- Software and Thin Client suppliers need to work together to enable their software to run on the system.

17.4 School 4

Overview

This is a co-educational primary school with 360 pupils on roll and 14 teachers plus the headteacher in total. The school's vision for ICT is to help meet the national curriculum targets, help teachers reduce their workload and to track pupils' progress in the school more effectively.

The school operates a hybrid network, with 30 Thin Client terminals, 38 Thin Client (legacy PC computers) on the Thin Client network and one terminal server. There are 20 other PC/laptop computers in the school to support the use of interactive whiteboards and some multimedia uses. There are six management and administration Fat Client PCs.

The hybrid Thin Client network and stand-alone PCs deliver all of the access to curriculum materials for students. A second Fat Client network is also in place to support the administrative staff.

A summary of these details is set out in the following table.

Size of school	360 pupils; 15 teachers (including head)
Thin Client Terminals	85 Terminals in total
Bespoke Thin Client terminals	30
Legacy computers used as Thin Clients	38
Other desktop computers and laptops used as Thin Clients	17
Bespoke Thin Client terminals as percentage of total Thin Client terminals	35%
Fat Client computers	26 (of which 14 are included in 'Other' above as they are dual-boot laptops)
Network details	
Age of Thin Client network	Approximately 3 years
Number of servers	1
Network specification	All devices are connected to the network at 100Mbps
Hybrid / pure Thin Client	Hybrid
System used for school administration	Fat Client
Average number of Thin Client terminals per server	85
Operating system	Windows Server 2003 Enterprise Edition

Reasons for implementing a Thin Client network

The main reasons for implementing a Thin Client network were to address a number of school requirements. The school previously had no IT suite and it was impossible to teach ICT as a subject and to integrate it with other subjects, but more space was needed for additional ICT resources. Under the National Grid for Learning Scheme (NGfL) finances became available to acquire a room and pay for greater ICT resources. After some research the school was convinced that a Thin Client network would provide a greater number of terminals and a more reliable system than could be acquired through a Fat Client system.

Teaching and learning benefits and issues

As with the other case studies, many of the benefits reported here could in theory be achieved through a similar Fat Client resource. However, it is because of being able to

obtain sufficient resources through the more economical Thin Client provision and its ability to enable older machines to remain in use that these benefits have arisen. It is therefore reasonable to attribute these benefits specifically to the adoption of the Thin Client network.

The greatest contributions of the Thin Client network have been increasing staff confidence because the system is so reliable, and providing more flexible ways of working. Most of the teachers have a very positive attitude towards ICT compared with seven years ago, and all teachers use it in different ways in their teaching. The school still has favourite software programs on the PCs, so their needs are met through a mix of Thin and Fat Client terminals.

Teachers can now have more flexible ways of working in planning and preparing their lessons because of the reliability of the network and having remote access from home (though this would also be possible using Fat Client technology). They are also able to monitor and report more effectively on pupils' achievements and progress than before.

There has been a significant increase in pupils' IT skills and confidence. The greater access to ICT introduced by the Thin Client network has enabled pupils to work independently more often and also enabled them to monitor their own learning. Pupils with special educational needs in particular have greater motivation and self-esteem.

Much of the curriculum activity is delivered via the Thin Client network. However, the administration network uses Fat Clients and teachers have Fat Client laptops which can be used to widen the capability of the network to support multimedia peripherals and the interactive whiteboards.

Though some multimedia programs do not run on the network, this was not seen by the school as a major disadvantage because many of these are used on the individual PCs and with the interactive whiteboards instead.

Technical support
The ICT co-ordinator and other key staff provide day-to-day support for the school. It also receives half a day per week support from a technician based at a local secondary school that has a specialist status as a Technology College. This support is largely used for installing new software on the Thin Client network and PCs, providing other support for the PCs and interactive whiteboards and resolving issues with printers and teachers' laptops.

The third-party provider maintains the system, performs remote fixes and also undertakes periodic (quarterly) site visits to complete health checks on the system.

Lessons learned
The key technology lessons learned and benefits gained from this deployment are as follows:

- The deployment of the Thin Client system has enabled the school to manage its administration overheads by centralising control and deploying terminals that require minimal intervention.
- The classroom atmosphere has been improved as the Thin Clients occupy less space, make less noise and output less heat.
- Investment in the correctly specified core infrastructure is absolutely key to the success of the deployment performance. Issues associated with performance are the most likely problems to be encountered.

Advice to other schools is not to opt for the cheapest and 'lowest' network because this will restrict the educational uses in the future and can result in a slow system in practice. (The school has had its network for over five years and is aware of more possibilities available with the latest Thin Client networks). One class teacher advised schools to 'get a system which can deal with everything you want to do without interfering with the existing stuff. You need to have a very good audit prior to commissioning installation and agreeing a contract.'

The key educational lessons and factors for success are as follows:

- The Thin Client approach provides significant savings in costs, better reliability and reduced technical support time. The school will never go back to traditional PCs.

- Performance issues remain, however, where resource-intensive applications are used, which include interactive internet services.

- It is very important, before making a decision to upgrade/change ICT resources, that there is someone who can answer all the questions the school needs to ask. An important strategy is to visit other schools that have already got a Thin Client network and can note their experiences and recommendations.

It is important to make sure at the onset that the supplier is going to be able to support a range of educational software on the network, not just the software recommended by the supplier.

17.5 School 5

Overview

School 5 is an 11 to 18 school with around 1000 pupils on roll and 94 teachers. The school's vision for ICT has two main goals: it should allow regular student and teacher access to ICT to support teaching and learning, and it should enable school management and administration to be streamlined.

Replacement of the school network began three years ago when the two existing servers were replaced; the network cabling was replaced two years ago. Thin clients and servers to support them were integrated into the network one year ago.

The school operates a hybrid network, with 56 bespoke Thin Client terminals, 39 legacy computers used as Thin Clients, 261 fat clients and 2 terminal servers as part of a 9 server network. There are 35 laptop computers provided via the school to teachers under the "Laptops for Teachers" scheme. The majority of the computers in the school are Fat Clients; a number of Thin Client terminals have been added where the school considers these would meet students and teacher' needs. Fat Clients are always used for applications that manipulate large files, such as video and photo editing packages. Laptops provided to teacher through the Laptops for Teachers scheme have been added to the school network as Fat Clients. The central server hardware and terminals were installed nearly a year ago, with an extensive wireless network being provided for the connection of both Thin and Fat Clients. The server and communications room is linked to the network by fibre connections to each floor of each building, with redundant links to provide resilience in the event of any failure of a fibre link. Thin Clients are supported by two network servers which were added to the existing network domain. Students and staff can access the school's network remotely. When they do so, they access their resources via a Thin Client session supported by the terminal servers, using the same username and password as if they were in school.

The hybrid Thin and Fat Client network delivers all of the access to curriculum materials for students. The school's management information software operates on Fat Client computers, which are part of the school's network.

A summary of these details is set out in the following table.

Size of school	970 pupils; 94 teachers
Thin Client Terminals	95 Terminals in total
Bespoke Thin Client terminals	56
Legacy computers used as Thin Clients	39
Other desktop computers and laptops used as Thin Clients	0
Bespoke Thin Client terminals as percentage of total Thin Client terminals	59%
Fat Client computers	261
Network details	
Age of Thin Client network	One year
Number of servers	9 (2 for Thin Client)
Network specification	Ethernet LAN
Hybrid / pure Thin Client	Hybrid
System used for school administration	Fat Client
Average number of Thin Client terminals per server	47.5
Operating system	Windows Server 2003 Enterprise Edition

Reasons for implementing a Thin Client network

The main reasons for implementing a Thin Client network were to address a number of school requirements, some of which could have been addressed by a Fat Client network if there had been sufficient funds.

- to have an ICT system which would meet the requirement to deliver the Government's target of 1 computer to every 5 students. The school needed to do this within the budget available, and found that a Thin Client solution offered more terminals for the budget available;
- a solution that could be maintained with little desktop maintenance for new machines, helping to keep support costs to a minimum by enabling existing IT staff to support more devices. An important consideration here was that the school wanted to deliver software upgrades and additional installations across the whole network. This was easier to achieve using a Thin Client solution, as some software running on the school's Fat Client machines requires manual upgrades or setting permissions manually on the computers themselves;
- school wanted a solution which was scalable at a low unit cost;
- a more consistent interface for both staff and pupils across all thin clients, wherever deployed.

The school found that the Thin Client machines exceeded their expectations in terms of speed and the range of software that they would support.

Teaching and Learning benefits and issues

The increase in the number of terminals and reliable and quick access to the network has encouraged staff and pupils to use ICT more in teaching and learning. A lot of the school's estate is Fat Client, and teachers and pupils do not really notice the difference between the

Thin and Fat Client sessions when working. The benefits reported were therefore largely to do with the increased reliability and functionality of the whole of the school's estate, compared with the network five years prior, which had been completely replaced. Reported benefits included:

- Teachers now have a much more reliable system which they can confidently use in their teaching and administration. This in turn results in more diverse ways of teaching and more flexible ways of working between lessons.

- Pupils can access the ICT resources in and out of lessons and can work in teams through accessing the school's network any time anywhere.

- Less able pupils are motivated by the power the system provides to help them with work presentation, and finding out new information raising their self-esteem and confidence.

Some issues were reported by the school, the main ones being the following.

- It was observed that at the time of the interview, not all software available on the Fat Client machines was available on the Thin Client servers, which meant that some teachers interviewed limited their use of software to that available over Thin Client machines, although there was specific educational software made available on Fat Client.

- Although the Thin Client network is capable of running various rich multimedia applications (perhaps because the network is only one year old and the servers are powerful), it was not able to support all those being used by the school. For example, video from one private sector source runs too slowly on Thin Client terminals, whereas multimedia science programs ran satisfactorily. The school uses Fat Client computers to run the applications that won't work satisfactorily on Thin Client terminals, although these are not widely used within the school.

- Although the assistant teacher reported that individual logging on and operation of terminals can be very slow at times particularly during lunch-times and after school, the systems have an uptime greater than 99% with all failures being attributable to hardware failure. The ICT co-ordinator, however, had not noticed any problems logging on, but acknowledged that Internet access could be slow at times of peak usage due to the available bandwidth (10Mb);

- Although the Thin Client devices do support USB memory sticks and cameras, they do not support USB devices which require local drivers to be installed, such as digital scanners. Neither do they support interactive whiteboards.

There was little evidence that the teacher and classroom assistant interviewed used a very diverse range of good educational software regularly on the network, such as computer based modelling, geography and history simulations etc. The feedback from the English teacher, ICT co-ordinator and class assistant indicated that most teachers simply used what was provided centrally. This approach, which needs further investigation, could be because of the reliability of software on the Thin Client network, which as reported in other case studies provided teachers with the confidence to use it on a regular basis. Although previous research (see for example Cox and Webb, 2004) has shown that such a situation can result in poor or superficial uses of ICT in teaching, the ICT co-ordinator and network manager comment that staff request curriculum resources via e-learning credits and to a very limited

extent their own budgets. Almost all requests are met, but it is acknowledged that the school has software which is underused.

Technical support

The school's staff is supported by a two-person team who provide day-to-day help and maintenance. In addition to this internal support, a third party informal arrangement is in place with the service provider that installed the original thin client servers and bespoke thin client terminals to provide advice on technical issues. This is provided in exchange for feedback from the school on the use of the Thin Client network, but is rarely needed now as the in-house expertise has grown to the point where all recent issues have been resolved by the school team.

Lessons learned

- It is essential to have an ICT expert who can research other schools and institutions to determine which is the best system to meet the school's requirements.
- The adoption of a hybrid solution by the school has enabled it to expand its ICT resources whilst keeping the costs to a minimum and meeting its current curriculum requirements although there is scope for more diverse uses of ICT in many curriculum areas.
- The more up to date and powerful the system is the more aspects of the curriculum it will be able to support.
- It is important not to be over anxious about investing in such a system because the benefits far outweigh the limitations.

17.6 School 6

Overview

School 6 is an 11–18 community college with over 1400 pupils on roll, 106 teachers and 106 support staff. The school's vision for ICT is to have a completely integrated system which meets all the needs of the school. 'My ultimate dream is to have totally integrated systems that are both seamless and robust' (headteacher).

This school operates a hybrid network of approximately 10 legacy PC machines only on the Thin Client network together with a very large number and range of other Fat Client machines which are connected to Fat Client networks. The school has about 655 PCs on a Fat Client network, 16 tablet PCs, 106+ laptops (one for every teacher and many more for support staff), and about 30 laptops for a special laptop project. The decision to deploy Thin Client technology was taken to provide remote access to many machines in and out of school.

A summary of these details is set out in the following table.

Size of school	1444 pupils; 106 teachers (including head) and 106 support staff.
Thin Client Terminals	10
Bespoke Thin Client terminals	0
Legacy computers used as Thin Clients	10
Other desktop computers and laptops used as Thin Clients	0
Bespoke Thin Client terminals as percentage of total Thin Client terminals	0%
Fat Client computers	655
Network details	
Age of Thin Client network	2 years
Number of servers	1
Network specification	Ethernet local area network
Hybrid / pure Thin Client	Hybrid
System used for school administration	Fat Client network, but can access remotely via Thin Client
Average number of Thin Client terminals per server	10 (with many more on occasional access)
Operating system	Windows Server 2003

Reasons for implementing a Thin Client network

The main reason for implementing a Thin Client network was to provide remote access from home for all staff and students and to be able to use older equipment to connect to the newer network. The school was developing the use of ICT at home and wanted all staff and students to be able to access the school's server remotely. Thin Client offered, in their view, the best way of meeting these needs.

Teaching and learning benefits and issues

The greatest benefit of the Thin Client server and provision of remote access from home has been to introduce much more flexibility into the way in which teachers can work. This is because the Thin Client providers have set up the network so that teachers can access the

school's server from home, a facility they did not have before (but which could equally be done using Fat Client technology).

The Thin Client network can be accessed from some fat client PCs and with the additional terminals allows greater access to ICT for pupils. This has increased their expertise and confidence although the technology itself could be mostly emulated with a different Fat Client system.

The greater flexibility 'enables pupils to do their homework after tea by remote access. This is an improvement because they do not do their best homework rushed at school when needing ICT access' (e-college manager).

The teachers have commented on the social skills being improved over those gained from working alone. If this project is successful then it will be extended to all pupils.

Whilst the system has been perceived to have limitations as it does not support the more media rich applications, it is believed that this limitation does not affect the learning experience because of the Fat Client network in the school. Those interviewed therefore thought that, within the bounds of the functions required from the Thin Client network (to support remote access to the school's network), there were no specific limitations.

Technical support
There are eight staff in the IT support team plus some support provided by some of the teaching assistants.

Lessons learned
This school had a clear single objective to resolve the requirement to expand access to ICT remotely whilst keeping costs to a minimum. The adoption of a Thin Client model with a few low-cost terminals and Windows 2003 operating systems has undoubtedly enabled the school to achieve this.

- The hybrid deployment supports the style of teaching and the delivery of the curriculum, and therefore the lack of support for high-volume multimedia applications is not an issue.
- The Fat Client network can do more because it is more powerful. Although the Thin Client network is fast and applications can be loaded up centrally, teachers would like to look at video clips and other rich media, so the school is gradually moving away from Thin Client to Fat Client machines for curriculum support. It is also possible to buy them almost as cheaply as Thin Client terminals as the costs are converging.
- The school has benefited from the experience of the current network management team in retrospectively applying a structured approach to design and performance improvements and this has been a factor in the ultimate success of the project.
- It is clear from the experience of this school that a structured design process and access to the correct expertise in the deployment phase is critical, as for any Thin Client solution. The investment in the server environment is key, whilst significant re-use can be achieved within the client base.
- Having standardisation of delivery has been the greatest benefit (according to the head of IT) as both networks and the laptops have the same desktop.
- Thin client networks are fine for using older PCs but this may be a false economy if Fat Clients are not much more expensive.

- The main advantage is providing access out of school and at home, which can extend the use of ICT in the school enormously.
- Problems can occur in maintaining the older PCs because it is difficult to get hold of parts.
- It is very important to consult widely before making any changes to the school's IT provision.
- 'Many schools still have a 70s mentality to try and adapt to the technology and are still using things off the shelf. Schools need to do things the other way round get the technology to adapt to the needs of education' (head of IT).

17.7 School 7

Overview

School 7 is an 11 to 18 co-educational comprehensive school. It has around 1400 pupils including around 280 in the sixth form. There are 90 teaching staff.

There are 80 bespoke Thin Client terminals and approximately 200 other computers capable of launching Thin Client applications through a web browser when required. There are four suites of Fat Clients, plus a number of other Fat Client machines deployed in classrooms and other areas, e.g. library. There are also 100 Fat Client laptops in use across the school: all teachers have a laptop and a number of legacy laptops have been redeployed for curriculum delivery.

The Thin Client network operates as part of a hybrid environment accommodating both Thin Clients and Fat Clients. This approach has been adopted to accommodate certain processor and memory intensive applications which do not run effectively over Thin Client and some applications which will not run at all.

Further details are set out in the following table:

Size of school	1400 pupils, 90 teachers
Thin Client Terminals	280 of which:
Bespoke Thin Client terminals	80
Legacy computers used as Thin Clients	0
Other desktop computers and laptops used as Thin Clients	200 (used as windows fat clients normally but which launch thin client applications through a web browser when required)
Bespoke Thin Client terminals as percentage of total Thin Client terminals	29%
Fat Client computers	100 (all of which can display applications from the Thin Client servers where necessary)
Network details	
Age of Thin Client network	7 Years, however migration to a windows based system has occurred more recently and upgrades are ongoing.
Number of servers	7 servers, including 2 Citrix Servers and 4 Windows Servers. There are numerous other infrastructure servers within the school however these are not strictly part of the Thin Client network
Network specification	All client devices are connected to the network at 100Mbps; servers are connected at 1Gbps.
Hybrid / pure Thin Client	Hybrid
System used for school administration	Fat Client
Average number of Thin Client terminals per server	40
Operating system	Windows 2003 and Citrix migrating to Solaris 10 and Tarantella

Reasons for implementing a Thin Client network

The school wanted to extend the life of the legacy infrastructure without employing a "big bang" change which would have alienated staff who were used to the legacy computers. Thin Client technology allowed this, and made possible a managed migration to the new platform over a year or so. The school also reports that the advantage of having around 200 Fat Client computers capable of launching a Thin Client session is that where the school only has a small number of licenses and do not know where the applications is to be used, then they can publish the application from a terminal server to be used wherever required.

Teaching and Learning benefits and issues

It is possible to use the Thin Client software anywhere in the school. Some departments use PCs but material can be delivered to these using the Thin Client servers. Because applications can be deployed within a browser window, applications that are occasionally used can be made available for use anywhere in the school with the number of concurrent users limited by the software. This means that more software is accessible. More money is being spent on software than used to be. This is because the Thin Client equipment lasts so long that money is available from the savings in maintenance and replacement. The software loads more quickly and the software environment is more easily managed than on the Fat Client network.

Those interviewed thought that the classrooms with Thin Client terminals in place are quieter and cooler.

The school is using Thin Client technology to export applications to students' homes via their broadband.

Having relatively new servers and network technology has made some multimedia accessible from Thin Clients. However, for multimedia work which places a heavier demand on servers for example, animation, digital video etc., the school still uses separate workstations. Real time applications such as video capture and capture from DV cameras and Midi keyboards also present a problem for Thin Clients. Those interviewed thought that this problem was diminishing due to higher specification network and server technology. However, for real time use, or where large amounts of animation are required and/or where peripherals are required, the school use PCs.

The system occasionally freezes and was thought to be a bit slow at times, but it was still thought to be useful.

Technical support

Whilst external maintenance and software subscriptions are purchased with all third party products, system configuration and administration are all undertaken in-house. In addition to the head of ICT there are three permanent network support technicians. The centralisation of administration and software installation was reported to be a benefit to the school with no upgrade maintenance needed on terminals.

Lessons learned

The consensus of those interviewed was that the school thinks that a mix of Thin Client and Fat Client technology in a school is needed but the possibilities of Thin Client technology seem well worth the money and effort spent in implementing it.

- The adoption of the technology enabled the school to expand its ICT environment whilst maintain support for the existing software suite, thus not imposing a major change on the end users.
- The deployment of the Thin Client system has enabled the school to manage its administration overheads by centralising control and deploying terminals that require minimal support.

17.8 School 8

Overview

School 8 is an 11 to 18 voluntary aided school. Its provision for 11–16-year-olds is for boys, with girls joining in the sixth form. There are 950 pupils on roll and 65 teaching staff.

The head's vision of ICT is that it is a tool to aid teaching and learning and should include a variety of techniques to achieve this. Ideally he would like to see an interactive whiteboard or its equivalent being used effectively in each classroom. In an ideal world he would like to have wireless access but due to the age of the building this is not possible.

The Thin Client network delivers all of the access to curriculum material for students. A Fat Client network is in place to support the administrative staff. The client estate consists of 120 Thin Client terminals. There are 14 Fat Client PCs on the admin network, and there are 65 stand-alone Fat Client PC workstations distributed through various departments. There are 36 laptops provided for teachers.

Size of school	950 pupils, 55 teachers
Thin Client terminals	120
Bespoke Thin Client terminals	120
Legacy computers used as Thin Clients	0
Other desktop computers and laptops used as Thin Clients	
Bespoke Thin Client terminals as percentage of total Thin Client terminals	100%
Fat Client computers	115
Network details	
Age of Thin Client network	3 years
Number of servers	8
Network specification	The network is 10/100mb fast Ethernet throughout
Hybrid / pure Thin Client	Hybrid
System used for school administration	Fat Client
Average number of Thin Client terminals per server	15
Operating system	Linux

Reasons for implementing a Thin Client network

The existing systems were poor, maintenance costs were very high and the school needed to expand its ICT environment but had limited funds available to do so. Thin Client technology was seen as the best way of doing this.

Teaching and learning benefits and issues

It was felt that because there was more ICT in school, this had a positive impact on teaching and learning and its use could be incorporated into lessons successfully. The reliability of the system was good, and it was thought that few problems were experienced with the use of Thin Client so lessons could start and finish quickly and there were no technical problems to prevent learning objectives being achieved.

Increased use of ICT, brought about by greater access to ICT enabled by the Thin Client network, was seen as a good way to differentiate lessons and to personalise learning. Using online packages, pupils could progress at their own rate and assess their work. Peer help and assessment had also increased.

Those teachers interviewed thought that staff needed more training on using the resources that were compatible with the Open Source software so that they could make greater use of them in lessons.

Pupils were given Open Source Software to load onto machines at home but declined to do so; they prefer to use Microsoft. However, this is not specifically a Thin Client issue but a choice to stick with a familiar application.

Apple Macs were in use in the music department because of the range of software used and the sophistication of the graphics in programs. The design and technology department used networked PCs as some of their software is not compatible with the Thin Client open source system adopted.

Technical support
All system management is undertaken in-house, whilst ad hoc software support is provided via informal internet support forums for the Open Source code. This has not presented any issues in terms of access to support and is free of charge.

Lessons learned
The main issue for the school was the need to expand access to ICT for staff and pupils and at the same time keep within a limited budget. Using free Open Source software and operating systems and adopting a Thin Client model with low-cost terminals has allowed the school to address this issue.

Those interviewed felt that the lack of support for high-volume multimedia applications is not an issue. Staff are aware that their preference for Windows applications (which do not run on this system), is subjective and not a technical limitation, so it does not affect the learning experience.

17.9 School 9

Overview

This is a co-educational, 11 to 18 comprehensive school. It has 1043 pupils on roll including a sixth form. There are 86 teachers and 114 staff in total. The school's vision for ICT is that it should be used to reduce workload for all staff, it should improve efficiency and it should extend learning.

The school operates a hybrid network, with approximately two thirds being Fat Clients and one third Thin Clients. The central server hardware was installed as new three years ago, while the network infrastructure was refreshed within the last two years. An extensive wireless network is provided for the connection of both Thin and Fat Clients. Depending on the terminal, users can either operate a Thin Client or Fat Client session over the network. Fixed Thin Clients are distributed throughout the various faculty class-room environments, whilst Thin Client laptops are used wirelessly to create ad hoc ICT environments in any classroom. The school maintains ICT suites, populated predominantly with Fat Clients.

Further details are set out in the following table.

Size of school	1043 pupils; 86 teachers
Thin Client Terminals	135 Thin Clients, of which:
Bespoke Thin Client terminals	30
Legacy computers used as Thin Clients	105
Other desktop computers and laptops used as Thin Clients	0
Bespoke Thin Client terminals as percentage of total Thin Client terminals	22.2%
Fat Client computers	289
Network details	
Age of Thin Client network	3 years: the central server hardware was provided as new 3 years ago, whilst the network infrastructure has been refreshed within the last two years
Number of servers	12 of which are 5 are used within the Thin Client server farm
Network specification	All client devices are connected to the network at 100Mbps; servers are connected at 1Gbps
Hybrid / pure Thin Client	Hybrid
System used for school administration	Fat Client
Average number of Thin Client terminals per server	11.25 (though the Thin Client servers do have different functions)
Operating system	Windows 2000 and Citrix

Reasons for implementing a Thin Client network

The school decided to implement a Thin Client network because of the state that the original ICT network had descended to: the network was a small, unreliable Fat Client network with only a single server. There had been no associated strategic development and it was impossible to deliver IT lessons as it was taking too long for students to log on. At the time the school believed that a Thin Client solution would be cheaper.

Teaching and learning benefits and issues
Greater provision of terminals with reliable and quick access to the network has encouraged staff and pupils to use ICT more. There have been some problems reported with difficulty accessing educational software, and unreliability of some of the legacy kit being used. Staff have reported more collaborative learning among pupils.

Multimedia applications are not run on their Thin Client network as they are particularly resource intensive and do not perform well on the school's Thin Client network. It should be noted that there are a number of graphics applications which are supported and delivered via Thin Client. This is because the volume of usage is very low and it has minimal impact on the network.

Where applications are certified for support over the Thin Client networks (either by the software developer or Thin Client network provider) those interviewed thought that the deployment was straightforward. Where software is not certified, this is tested within the Thin Client network, and should the implementation not be successful, a Fat Client deployment is undertaken.

Some departments, particularly music and design and technology, have found limitations in the use of Thin Client when they are using programs that use a lot of graphics, are interactive or have sound (no sound functionality is available through the Thin Client terminals). Hence, they use PCs (known in the school as Power PCs). When using certain software, the Thin Client network slows and 'grinds to a halt' (Head of ICT) if too many students log on at once. The technology department uses control modelling packages and CADCAM which do not run on Thin Client. Certain peripherals also do not function on the Thin Client terminals.

The school has also found some problems with the reliability of legacy PCs used as Thin Clients.

Technical support
Subsequent to the deployment the school has appointed two full-time staff: a network manager and a technician (though these people do more than support the Thin Client network). In addition to internal support, a third-party maintenance contract is place with the service provider that deployed the original network. The school tries, in the first instance, to solve technical issues, only resorting to the third party where they are unable to find a solution.

Lessons learned
- The adoption of a hybrid network has been the pragmatic foundation for success. By taking this approach the school has been able to resolve many of the performance issues experienced within the education environment and increase the longevity of at least a third of its client estate.
- The school emphasised reliability as a key factor for adoption: lessons can be planned and go ahead with very infrequent, if any, technical problems.
- The system supports standard Microsoft operating systems and software. This has enabled the system to be introduced with the minimum of change apparent to the user. It is highly likely that this has been a significant factor in the widespread acceptance of the network.

17.10 School 10

Overview

School 10 is a small mixed secondary school with 740 pupils and 50 teachers (45 FTE).

The school has adopted a complete Thin Client approach for student access to ICT, whilst a small Fat Client network is maintained to support media-rich applications. The Thin Client system is built on a Citrix-based Thin Client network. Teachers also use laptop computers with Fat Clients: these are mainly used as stand-alone devices but with access provided via wireless connection to the Thin Client network.

The approach to ICT in the school is that it should firstly be used as a tool for supporting learning across the curriculum and for learning about ICT. Its use in the curriculum should be done in a natural way. The school has been to be able to use existing curriculum resources when upgrading to a new hardware solution so this has influenced the choice about which type of ICT network should be purchased when expanding.

The role of ICT in the school has been steadily growing owing to the enthusiasm and expertise of the school staff. For example, the school was part of the pilot project for the introduction of the National Grid for Learning in 1997 and introduced the Thin Client network in the same year.

Size of school	740 pupils; 50 teachers
Thin Client Terminals	208
Bespoke Thin Client terminals	122
Legacy computers used as Thin Clients	8
Other desktop computers and laptops used as Thin Clients	78*
Bespoke Thin Client terminals as percentage of total Thin Client terminals	58.7%
Fat Client computers	Not known
Network details	
Age of Thin Client network	9 years
Number of servers	13
Network specification	Ethernet LAN
Hybrid / pure Thin Client	Hybrid
System used for school administration	Fat Client
Average number of Thin Client terminals per server	16
Operating system	Windows Server 2000 and Citrix

*This does not include the 50 laptops provided to individual teachers

Reasons for implementing a Thin Client network
The main reasons for choosing a Thin Client network to upgrade the ICT resources were:

- the need to increase the number of computers/terminals in the school to enable ICT to be used in all curriculum subjects
- the need to use the existing machines (Acorn computers) and the educational software already being used alongside newer machines
- the school's desire to purchase a system which would provide a large number of terminals for a limited budget.

Teaching and learning benefits and issues
According to the headteacher, the Thin Client network had significantly affected the way in which the whole school, including teaching, worked. Teaching had changed by increasing the regular use of ICT in many lessons but also by teachers being able to prepare lessons using ICT beforehand and being able to rely on the ICT activity in the lesson working each time. Having the Thin Client network has increased the use of ICT across the curriculum, and teachers' ICT skills were improving, with some teachers previously nervous about using ICT now confident to use the network. Following the installation of the Thin Client network, the standards in the students' ICT skills were increasing every year and in some other subjects too. The headteacher reported a significant change in the students' attitudes to music because of what they could do with ICT, including composing their own music – some had become 'addicted' to this activity. However, 'the jury is out' on the impact the Thin Client network has had on other learning in the school.

In the ICT co-ordinator's view, the greatest impact on teaching was related to the greater control which teachers had over their lessons because it was not possible for either teachers or students to 'tinker with the machines'.

The school does not deliver multimedia applications across the Thin Client network. One limitation on teaching due to the Thin Client network was its current inability to run multimedia software, especially video clips and sound. However, the ICT co-ordinator reported that this situation is gradually changing with the faster connections and more powerful Thin Clients. It was now possible to run some measurement and control devices through local USB ports on the Thin Client network although the school was thinking of purchasing some new dedicated PCs for the more powerful educational software such as for music editing and media-rich applications in other subjects.

One of the problems reported by the teacher was that there was still pressure on time-tabling of ICT suites.

Technical support
All system management is undertaken in-house, whilst software support is provided via formal support by a third-party company. The support for the Thin Client network is provided by the ICT co-ordinator, the network manager and the technician with back-up from the network provider. The school regarded this back-up support as very important. It was essential for the provider to be able to respond at short notice and to work with the school in overcoming limitations such as the functioning of multimedia software.

Lessons learned
There were some recommendations for other schools who might want to upgrade and expand their ICT resources, and some advice about the limitations:

- It is very useful to visit and consult other schools before deciding what kinds of ICT resources are best and which provider to use.
- Some providers' licensing arrangements can be expensive.
- It is important to get a powerful enough system to be able to cope with the sheer volume of traffic on the network.
- It may be necessary to have a small PC network to enable more powerful software to be used, but this can still also run on the Thin Client network.

17.11 School 11

Overview
This is a large co-educational comprehensive school with Specialist School Status. It serves a wide range of communities ranging from those who are economically prosperous to those who are significantly disadvantaged. There are 2000 pupils on roll, including a large sixth form and there are 120 teaching staff.

The school's vision for ICT in the school is that it wants to offer alternatives to young people to broaden their learning experiences. It wants them to be able to access resources when it suits them and it wants ease of access for inclusion and literacy. It wants ICT used as a resource giving an opportunity for pupils to be creative and for ICT to be part of their normal 'educational diet'.

School 11 is a very large school with an extensive ICT environment. The current school buildings are only some six years old and therefore much of the ICT deployment strategy was formulated as part of the equipping of the new environment. In addition to this, significant expansions have taken place over the last five years.

The network is a hierarchical model. This is distributed across two core communications rooms. Additional switching nodes are situated in three other faculty locations, all of which are connected resiliently to the dual core within the primary communications room. A number of the access switches are enabled for Power over Ethernet to support the wireless environment.

Size of school	2000 pupils; 120 teachers
Thin Client Terminals	300 Thin Clients, of which:
Bespoke Thin Client terminals	0
Legacy computers used as Thin Clients	200
Other desktop computers and laptops used as Thin Clients	100
Bespoke Thin Client terminals as percentage of total Thin Client terminals	0%
Fat Client computers	Not known
Network details	
Age of Thin Client network	5 years, however several subsequent upgrades have been undertaken
Number of servers	6 servers are deployed within the farm (1 being dedicated to administration). Many other servers exist to support infrastructure requirements beyond the Thin Client network.
Network specification	All client devices are connected to the network at 100Mbps; servers are connected at 1Gbps
Hybrid / pure Thin Client	Hybrid
System used for school administration	Hybrid, but predominantly Thin Client
Average number of Thin Client terminals per server	50
Operating system	Windows 2003 and Citrix, with Linux on the desktop for Thin Clients

Reasons for implementing a Thin Client network
When the new school was being built in 2000, the school wanted as many people as possible to have access to online working for both administration and in the classroom. They wanted a financially effective network and at that time decided it would be Thin Client. The Thin Client network was seen as a cheap alternative and it is seen now as a stepping-stone to Fat Client when the money becomes available. At the time of its installation the school was doing very little multimedia work so this was not an issue.

Those interviewed thought that Thin Client was installed at a time when it was of maximum benefit to the school and a lot of work was done using it. Now it is felt that the school is in a different phase and they are looking to switch to Fat Client to meet their needs.

Teaching and learning benefits and issues
The availability afforded by the installation of the Thin Client network has led to ICT being incorporated more widely into all aspects of the curriculum than in the previous school building. It can be used particularly effectively for research tasks and for data handling across a wide range of subjects. Word processing packages are commonly used to enhance the quality of presentation of work.

The reliability of the Thin Client system had encouraged more ICT to be used in lessons than in the previous school building and had given confidence to both staff and pupils.

Multimedia applications are not deployed on the Thin Client network as they do not run efficiently and affect the performance of the rest of the network. There were concerns expressed about the ability of Thin Client to deliver new examination specifications with the limitations of multimedia and sound. These limitations were also considered to be demotivating to pupils, some of whose skills were very advanced. It was also felt that these limitations were hindering closer collaboration between the technology and arts departments. This was of particular significance given the school's specialist status in these two curriculum areas.

Teachers interviewed thought that Thin Client was not meeting the changing nature of examination courses and the type of software that was now being more widely used.

Technical support
All technical support is provided in--house by a team of four technicians, an application administrator for the school's management information system, and two in-house developers.

The current staffing level has expanded as a result of the expansion of systems rather than the adoption of Thin Client. No additional training was given to the members of staff relating to the Thin Client system. There is no external support arrangement in place with the Thin Client software provider.

Lessons learned
- Thin Client was viewed as a quick way to put computers widely throughout the school at low cost. At the time of its installation, it was fit for purpose and enabled staff and pupils to have good access to ICT.
- As the needs of the school have grown and new examination syllabuses have been developed, it is thought by the school that they have outgrown Thin Client and that a Fat Client network will better serve their needs. This is not seen by the school as a negative reflection of Thin Client per se but as a change in the school's needs.

17.12 School 12

Overview

School 12 is a co-educational community college specialising in mathematics and computing with 1400 pupils on roll and 103 teachers (82 FTE) and 103 support staff in total. The school's vision for ICT is to have an ICT environment which is 'fit for purpose and where people are not afraid to ask questions, where ICT becomes second nature to everything we do' (headteacher).

This school operates a hybrid network of approximately 540 Thin Clients. The school also has 192 stand-alone desktop Fat Client PCs and 182 laptops.

A summary of these details is set out in the following table.

Size of school	1400 pupils; 103 teachers (including the head), 103 support staff
Thin Client Terminals	540
Bespoke Thin Client terminals	490
Legacy computers used as Thin Clients	50
Other desktop computers and laptops used as Thin Clients	0
Bespoke Thin Client terminals as percentage of total Thin Client terminals	91%
Fat Client computers	192 PCs, 182 laptops
Network details	
Age of Thin Client network	2 years (4 months for current system)
Number of servers	12 in total
Network specification	Ethernet local area network
Hybrid / pure Thin Client	Hybrid
System used for school administration	Thin Client
Average number of Thin Client terminals per server	58.3
Operating system	
Bespoke Thin Client terminals	Windows Server 2003 Enterprise Edition

Reasons for implementing a Thin Client network

The main reason for implementing a Thin Client network was that the school needed to replace the old system to meet the growing needs of a large school population (1606 students and staff) and have a system which would fulfil the teaching and learning requirements. Specific reasons were that the school wanted to retain use of its significant number of existing PCs (over 200) and to have an ICT environment which was fit for purpose and would meet the needs of the National Curriculum.

The school had a Fat Client network previously but the soaring cost of maintenance and management was the key driver for moving to a Thin Client network. Therefore options to upgrade the Fat Client network were discounted on delivery capacity, scalability and commercial grounds. The decision to deploy Thin Client technology was taken partly for economical reasons, which included predicted lower maintenance, training and management costs, and partly because the school needed to be able to extend the ICT resources at the

same time as being able to use the existing ones. The overall aim was to extend its ICT resources to deliver the curriculum at the lowest possible cost.

The option selected was to adopt a high-specification Thin Client network. In this instance, the school selected Windows 2003 Enterprise Server as a Thin Client server technology.

Teaching and learning benefits and issues

- Because of the large number of Thin Client terminals which the school has (480 altogether) and another 220 PCs, there is a growing use of ICT both in and out of school hours with many teachers working at home preparing lessons and marking homework online.
- There is evidence of greater autonomy amongst many pupils because they are expected to work on their own more.
- 'Pupils learn at their own pace without the social pressures from their peers and we see them concentrating and achieving more because of it' (business manager).
- There have been significant improvements in Year 11 results because of access to richer sources of materials over the internet to assist research.
- There is still uneven use of ICT amongst teachers, with some complaining of not having enough educational software.
- Using ICT resources on the Thin Client network for absence cover has greatly enhanced the organisation of teaching in the school and the learning experiences of the pupils. The previous ad-hoc supply cover scheme was replaced through the use of subject work on the network. The school has appointed two permanent assistant learning managers to supervise two rooms in which up to 7-9 classes for Years 7, 8 and 9, can be working whenever a teacher is away. This arrangement both provides much greater continuity in teaching and also reduces costs to the school.
- Remote access to the school's network has spawned new methods such as marking homework delivered online on PC Tablets and liaising with groups of pupils in between lessons.
- Discipline is improving in the school because reports with recommended detention can now be processed in a day where previously they took a week.
- With such an extensive network in the school some teachers had difficulty in grasping the concept of multimedia programs not being able to run on all machines.

Technical support

There is now a broad technical team of five people consisting of the ICT co-ordinator, the head of ICT, one technician, and a network manager led by the business manager of the whole school.

Lessons learned

Those interviewed reported many factors linked to the success of the Thin Client network in the school and lessons which will be useful to other schools. These include the following:

- It is important to have experts in the school or access to education/IT experts to be able to make informed decisions about which network to obtain.
- The investment and cost of all the resources need to be balanced against other advantages such as reducing the cost of supply cover.

- Make sure that the Thin Client network will "do what is says on the tin" (business manager) before deciding which supplier to use.
- It is very important that school staff understand how the network works and what its potential is.
- A Thin Client network has a much smaller footprint, so more machines can be used in the same space compared with PCs.
- Using a hybrid system can ensure that both generic software and media-rich software can be used to their best advantage in a school.

Those interviewed thought that the school would never return to a Fat Client system.