THE FUTURE OF INFORMATION TECHNOLOGY IN UK SCHOOLS

McKinsey & Company

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CONTENTS

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PREFACE

This report was developed by McKinsey & Company, with the aim of producing a completely independent analysis of the issues, challenges, and opportunities surrounding the use of information technology in schools, and of the options for policymakers in general. The report incorporates findings from a series of discussions with educators, public bodies and industry participants.

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EXECUTIVE SUMMARY

The UK has a higher ratio of computers per schoolchild than almost any other country, including the US. Yet despite this lead and the fact that information technology has been on the educational agenda for almost 30 years, it is not clear that IT has made a significant impact on educational standards. The reason is not that IT is irrelevant to education – it has the potential to enhance and even transform elements of teaching. Rather, it is that many IT initiatives in schools have focused on just one area, often the provision of hardware, at the expense of addressing more widely how computers can be fully integrated into education.

With the Internet bringing new possibilities as computers become not just a tool for processing information but a vehicle for communication and exploration over networks, the UK is at a crossroads. It needs clearer educational objectives for IT, and a cohesive approach to enable them to be achieved.

The purpose of this report is to provide a review of the opportunities, challenges, costs and benefits of incorporating IT more fully into the educational system, and to give policymakers a basis for decisions.

The report has six main sections.

1. The history of IT in schools up to the present day

The emphasis of IT policy in schools has historically been on installing hardware, largely as a result of an initiative in the early 1980s in which the government teamed with local authorities to provide at least one computer in every school. There are now on average 85 computers in each secondary school and 10 in each primary school, putting the UK ahead of most other countries in terms of availability of basic hardware. The market has come to be dominated by two suppliers, Acorn and RM, with a community of small UK educational software developers writing mainly for the Acorn machines.

2. Today's limitations and the variations in how IT is applied

Although the hardware situation at first sight appears healthy, there are wide variations in provision between schools and between the primary and secondary sectors. In 40 percent of primary schools, for example, there is only one computer for 20 or more children. A high proportion of these machines are obsolete, and IT training for teachers is limited.

In terms of how IT is applied, some schools use computers as a teaching tool frequently and some not at all. While IT has been found to contribute significantly to learning in maths, primary-level English and secondary-level geography, the impact in other areas is more mixed.

3. The challenges, opportunities and the need for an integrated approach

Today's mixed pattern of results stems from a lack of clarity over educational objectives for IT and the fact that the focus on installing hardware has left other issues on the sidelines. A more fully integrated approach is needed. This does not imply a large, centrally funded initiative. There is much momentum from local authorities and schools themselves, but it has to be channeled more effectively and consistently across the country.

Schools need a broader vision of how IT can be used that goes beyond just using spreadsheets in maths and wordprocessing in English. There are many possibilities. For example, content-rich software such can be used to aid the teaching of geography and history and interactive tuition courses can be used to teach modern languages. IT can be employed in group work or to help individuals learn at their own pace. Integrated learning systems, which include mechanisms for tracking and reporting a child's progress, have been shown to be beneficial in raising basic numeracy. Links to the Internet can give teachers support, training and the ability to communicate.

The growth in home computers also opens up opportunities to extend learning beyond the classroom. Five million computers have been purchased for the home since 1989, representing 22 percent of UK households. The accompanying shift in children's use of leisure time away from watching television and towards using computers and games devices, means the home market represents a considerable educational opportunity, and one that is largely untapped.

But probably the most significant development in computing in the past decade has been the emergence of networks and the potential they offer schools to communicate internally and with the outside world. Trials of networked learning at a Kent grammar school have thrown up a range of possibilities: children publish their own work in poetry and art; the school has links to the Natural History Museum, the Science Museum and ecology and astronomy sites; and pupils studying modern languages practise by exchanging e-mails with students overseas.

A logical extension of networking is learning within the community, whereby computers in schools, libraries, other public buildings and potentially the home all have access to a common set of networked resources.

4. The issues to be resolved

Before these opportunities can be realised, certain needs must be addressed. These are: the need to clarify educational objectives for IT, to support teachers, to tackle the fragmented supply of software, to bring down the costs of external networks and to upgrade hardware.

Educational objectives. We need to be clearer about what we want children to learn, and whether learning should be about acquiring vocational skills or about learning for its own sake. We need to decide where learning should take place, and the correct balance of resources between primary and secondary education. And we need to be clearer about how children can be enabled and encouraged to learn. Are selection and streaming preferable to mixed-ability classes? Should children be taught in large or small groups? How much time should be spent learning? What balance should be struck between prescriptive and child-centred teaching? And how should children be assessed?

Whatever philosophy is followed, links have to be made between those educational objectives and the objectives for IT.

Supporting teachers. Training has emerged as one of the most important issues. IT tuition at teacher training colleges is at present limited to 20–30 hours and there is little or no subsequent training, with the result that the IT skills that teachers have quickly become outdated.

Fragmented software supply. There are over 200 software developers producing packages for the UK educational market, but most are very small and cannot invest sufficiently to develop more substantial products that would cover a broader range of the curriculum. Acorn's strong market position, and the fact that it relies on a proprietary operating system, has created a mutual dependency between it and educational software suppliers. Acorn needs them to supply software for its particular system; they rely on Acorn because they are excluded from markets that use more universal operating systems. Also, although there are a large number of software packages, many overlap and address similar objectives. What is more, there is no ratings system to help teachers and parents decide packages' relative merits.

Network costs. Rates which vary according to how much external network capacity is used make budgeting uncertain. At today's commercial rates even a relatively small capacity permanent connection to the Internet – enough to connect six to eight computers simultaneously to the World Wide Web – would be around £7,000 a year.

Modernising hardware. There are real limitations on the value of existing hardware. About half of the machines in schools are over five years old; therefore the need is to upgrade machines so that they can run the latest software.

5. How these issues might be resolved

A centrally driven policy aimed purely at increasing the number of computers would be inappropriate. A smaller, but coordinated set of initiatives could tackle the issues above in the ways outlined below.

Educational objectives. Whatever educational philosophy one espouses, IT opens up new possibilities for supporting it. For example, prescriptive teaching can be assisted by integrated learning systems. Whole classes and individuals alike can explore sources of information through networks.

Supporting teachers. Teachers have three principal needs: training, access to computers and a means of communicating. Training colleges could rethink their approach to technology training, and one or more of the ‘Baker Days’ built into the educational calendar for training purposes could be earmarked for IT. Computers could be given to teachers directly, or teachers could be allowed to offset their own purchase of machines against income tax. A Web site with a series of bulletin boards would enable them to communicate.

Fragmented software supply. There are various measures government could take to stimulate the growth of a more substantial software base. The schools market on its own is often insufficient to justify the investment software companies would need to make to develop modern applications. But a ratings system that would help parents as well as teachers discriminate between packages would open up the home market to suppliers.

Network costs. Cable companies have started to offer flat rates to schools and other telecommunications providers might follow suit. Costs can also be minimised within schools. In a US ‘Net Day’ initiative, for instance, volunteers from local communities and businesses using donated equipment helped to wire up their schools.

Modernising hardware. Whilst this report does not seek to make any recommendation for a particular level of provision in schools, we have, purely for illustrative purposes, analysed the costs of various indicative configurations of school infrastructure and external network connections. These are:

- ***A computer 'laboratory' model*** in which each primary school would have enough computers in a single room for one class and each secondary school enough in three rooms for three classes.

- ***A 'demi-classroom' model,*** with computers distributed throughout the school (both primary and secondary), with five machines in every other classroom.

- ***A 'classroom' model*** – similar to the demi-classroom model but with five computers in every classroom.

- ***A 'desktop' model*** that would provide one computer per child.

6. Achieving the right balance and focus

In deciding the balance and focus of IT opportunities a number of factors are relevant. The first is the balance of spending between primary and secondary schools. Secondary schools have received a higher level of IT provision, yet areas in which IT has an important role to play, such as improving basic numeracy and literacy, could more valuably be tackled at primary stage, before children fall behind.

The second factor is the extent to which resources should be directed towards teachers. Without proficient teachers, any other investment in IT in schools is likely to be wasted.

The third is financing. The main challenge in this area is to stimulate and channel local momentum and funding. But the amount local authorities and schools need to spend on technology has to be considered in terms of the overall education budget. Finally, although beyond the scope of this report, there is a possibility that in some areas, by increasing productivity, IT might actually reduce certain costs.

INTRODUCTION

The UK has a higher ratio of computers per schoolchild than most other countries. Yet despite this lead and the fact that information technology has been on the educational agenda for almost 30 years, it is not clear that IT has made a significant impact on standards of education. The reason is not that IT is irrelevant to education – it has the potential to enhance and even transform elements of teaching. Rather, it is that many IT initiatives in schools have focused on one area, often the provision of computer hardware, at the expense of addressing how computers can be fully integrated into education.

With the Internet bringing an explosion of new possibilities as computers become not just a tool for processing information but a vehicle for communication and exploration over networks, the UK is at a crossroads. It needs clearer educational objectives for IT, and a cohesive approach to enable them to be achieved.

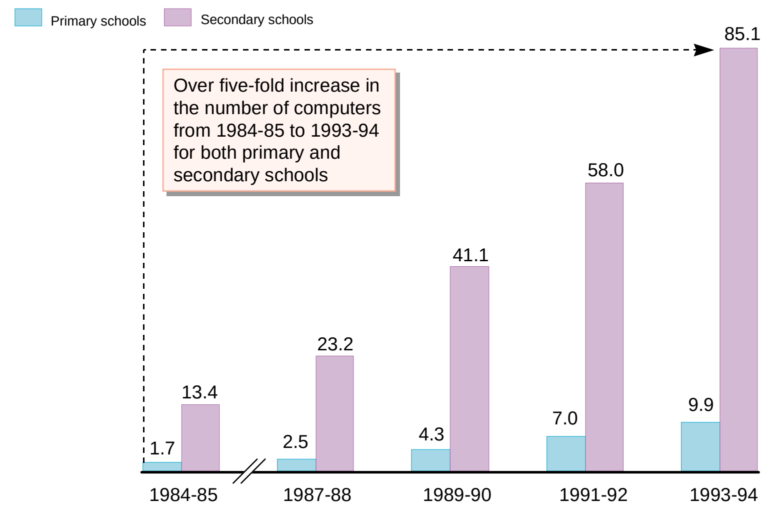
The purpose of this report is to provide an objective review of the opportunities, challenges, costs and benefits of incorporating IT more fully into the UK educational system, and to give policymakers a basis for decisions. It is founded on an analysis of how IT is being applied today and the new possibilities that are emerging, and reflects interviews we have conducted with educators and industry participants. The report's main sections are:

- The history of IT in schools up to the present day.
- Today's limitations and the variations in how IT is applied.
- The challenges, opportunities and the need for an integrated approach.
- The issues that need to be resolved in order to realise the opportunities, including clarifying educational objectives for IT, support for teachers, software supply, the costs of external networks, and upgrading hardware in schools.
- How these issues might be resolved.
- Achieving the correct balance and focus.

HISTORY OF INFORMATION TECHNOLOGY IN UK SCHOOLS

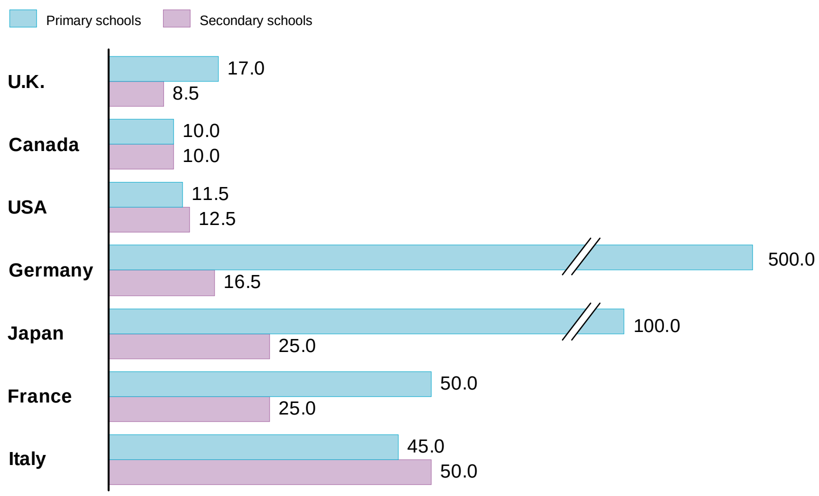
Between 1984–85 and 1993–94 the number of computers in UK schools grew more than fivefold, to reach an average of 85 computers in each secondary school and 10 in each primary school. This puts the UK ahead of most other countries in terms of availability of basic hardware (Exhibits 1 and 2).

Exhibit 1 AVERAGE NUMBER OF COMPUTERS PER SCHOOL*



* England only
Source: *Survey of Information Technology in Schools*, Government Statistical Service, February 1995

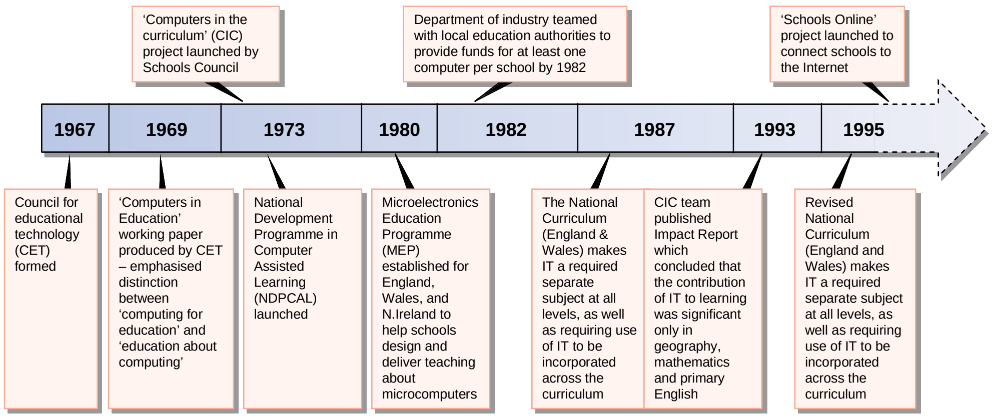
Exhibit 2 NUMBER OF PUPILS PER COMPUTER BY COUNTRY, 1995



Source: RM International Report on IT Provision in Schools, Draft July 1996

This pattern of infrastructure arose from a series of actions in the late 1970s and early 1980s (although IT was on the educational agenda as early as 1967, when the Council for Educational Technology was formed). In the early 1970s, the Schools Council launched a project to explore ways to use computers in the curriculum. In 1980, the government's Microelectronics Education Programme was set up to teach schoolchildren microcomputing as a subject in its own right. But the turning point came in 1982, when the government teamed up with local education authorities to provide funds for at least one computer in every school. From that point the installation of hardware gathered momentum, stimulated by the government requirement that IT be included in the National Curriculum (Exhibit 3).

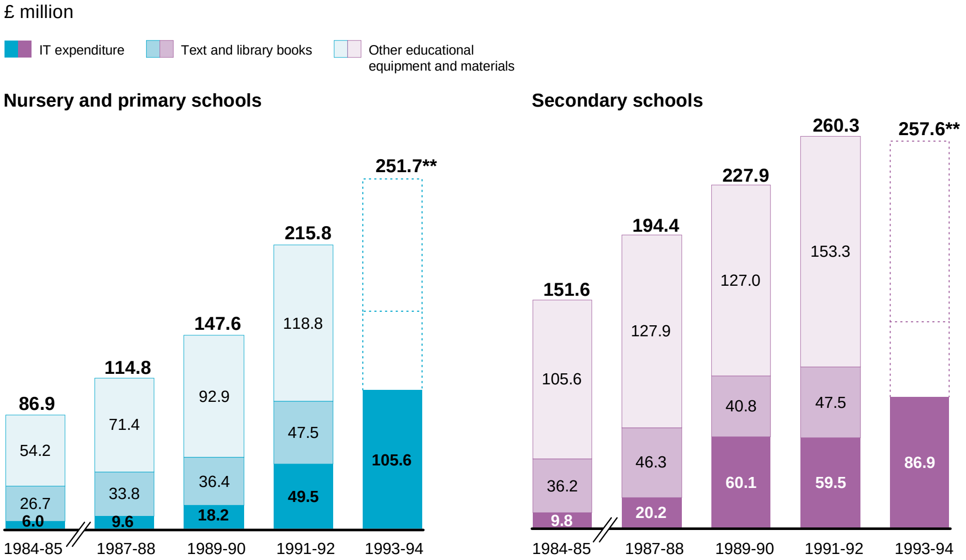
Exhibit 3 INTRODUCTION OF INFORMATION TECHNOLOGY IN EDUCATION



Source: *"Developing a whole school IT policy"*, Bill Tagg, 1995; Press clippings

The amount schools have invested in IT has since risen from £16 million a year in 1984 to just under £200 million a year in 1994. This sum represents approximately one-third of total school expenditure on educational equipment and materials (Exhibit 4).

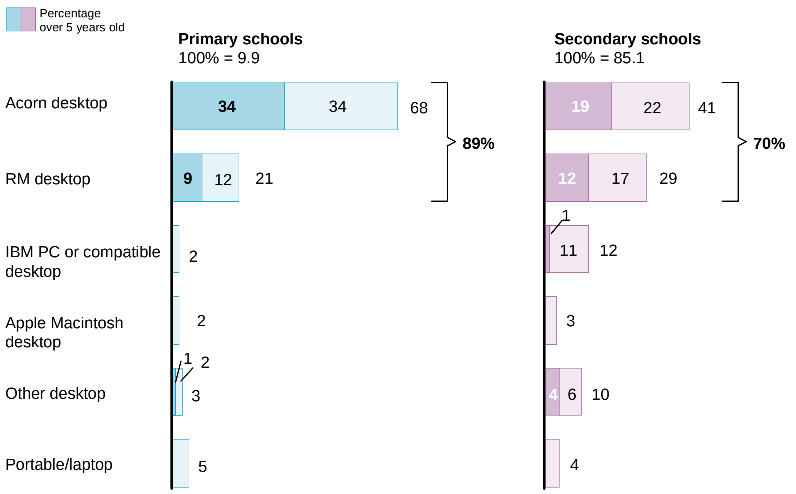
Exhibit 4 SCHOOL EXPENDITURE ON EDUCATIONAL EQUIPMENT AND MATERIALS*



* England only
** Details on the spend on text and library books were not collected for 1993-94
Source: Educational expenditure statistics for England, DFE; "Survey of Information Technology in Schools", DFE, 1995

The early emphasis on hardware influenced the development of the UK computer market. At about the same time as the government launched its 1982 initiative, Acorn Computers, then a new company based in Cambridge, released – with the BBC's backing and branding – the BBC microcomputer. This relatively inexpensive machine rapidly became the standard in many schools. Along with its descendants, it was based on a proprietary operating system which attracted a community of loyal, but mainly small, software developers, writing specifically for the UK education market. The second main hardware supplier is RM (formerly Research Machines). It based its first educational computer, released in 1977, on an early microcomputer operating system, then switched to Microsoft's MSDOS operating system in the mid-1980s when it became clear this would become a leading worldwide industry standard (Exhibit 5).

Exhibit 5 SUPPLIERS OF DESKTOP COMPUTERS TO SCHOOLS, 1993-94*
Percent

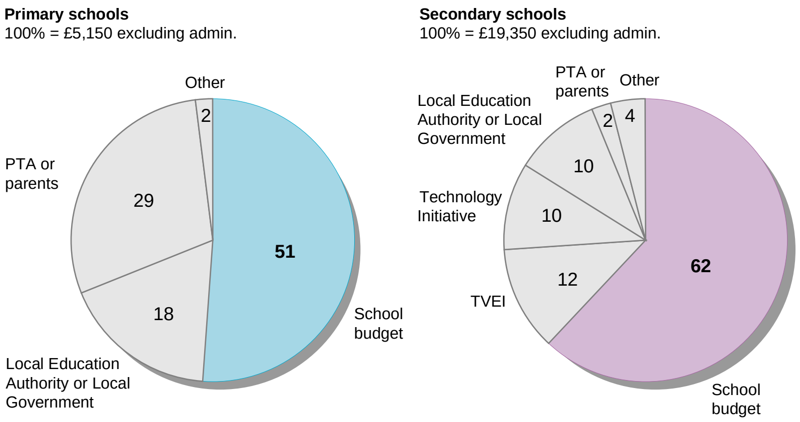


* England only
** RM estimates highter market shares in 1996 of 30% in primary; 50% in secondary
Source: *Survey of Information Technology in Schools*, Government Statistical Service, February 1995; interviews

As a result of their early initiatives, Acorn and RM now dominate the UK educational market. RM is stronger in secondary schools, where its share rose from 29 percent in 1993–94 to about 50 percent by 1996. As well as hardware, it provides internal networks and support services. Acorn, which recently joined Apple Computers in an educational joint venture named Xemplar, is relatively strong in primary schools, with approximately 70 percent of that market.

Although central government provided the backing to install hardware in the early 1980s, much of the momentum since then has been provided by local decision makers. About 70 percent of expenditure in 1993–94 was discretionary, paid out of local authority and school budgets, while individual schools made their own decisions on hardware and software. Whilst this local momentum has substantially increased the availability of computers in schools, it has led to wide variations between districts and schools in how IT has been applied (Exhibit 6).

Exhibit 6 DECENTRALISED NATURE OF FUNDING FOR IT IN SCHOOLS, 1993-94*
% of expenditure



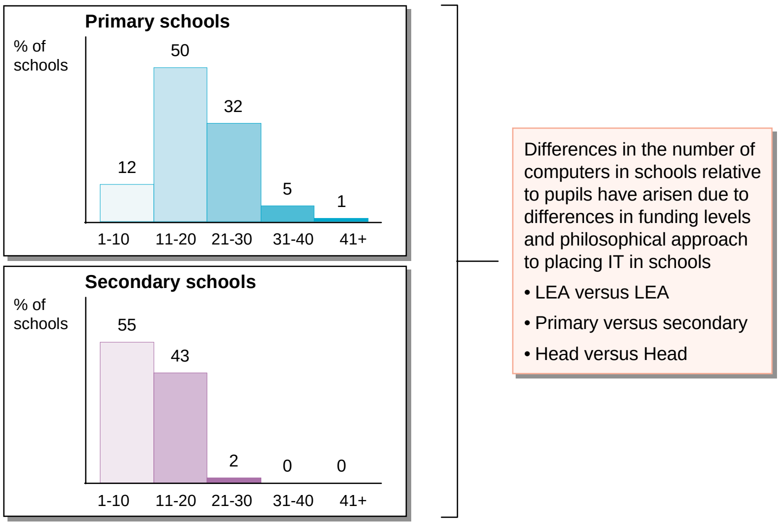
* England only
Source: *Survey of Information Technology in Schools*, Government Statistical Service, February 1995

Recognising the need for national coordination, the government established (for England and Wales) the National Council for Educational Technology (NCET), a charity funded largely by a £5 million government grant. Its aim is to identify the relevance of new technologies to education, to evaluate their potential to enhance learning and raise standards, and to promote and support technology use across all educational sectors. It mainly provides information and support materials: it publishes a review of CD-ROMs, for example, and researches the effectiveness of interactive educational software. The corresponding organisation for Scotland (SCET) takes a different approach. Less than 40 percent of its income in 1994–95 came from Scottish Office grants, the balance being made up from commercial activities and sales to education authorities. SCET produces educational software (its Writers' Toolkit helps children develop writing skills and structure clear storylines, for example) and provides resources for teachers, management information software for schools and IT training services for educators and local businesses. It also runs the SCET Technology Centre, an interactive learning 'laboratory' where pupils, teachers and parents can try out educational software and obtain advice and support.

TODAY'S LIMITATIONS

This apparently healthy level of hardware provision belies the real state of affairs, however. First, there are substantial variations around the averages between individual schools, and between primary and secondary sectors. Many of these are due to the different priorities and attitudes of local education authorities and head teachers. In almost 40 percent of primary schools, for example, there is only one computer for 20 or more children. Secondary schools show similar variations, although the level of overall provision is higher and only 2 percent of schools have more than 20 pupils per machine (Exhibit 7).

Exhibit 7 WIDE VARIATIONS IN PUPIL TO COMPUTER RATIOS
1993-94*

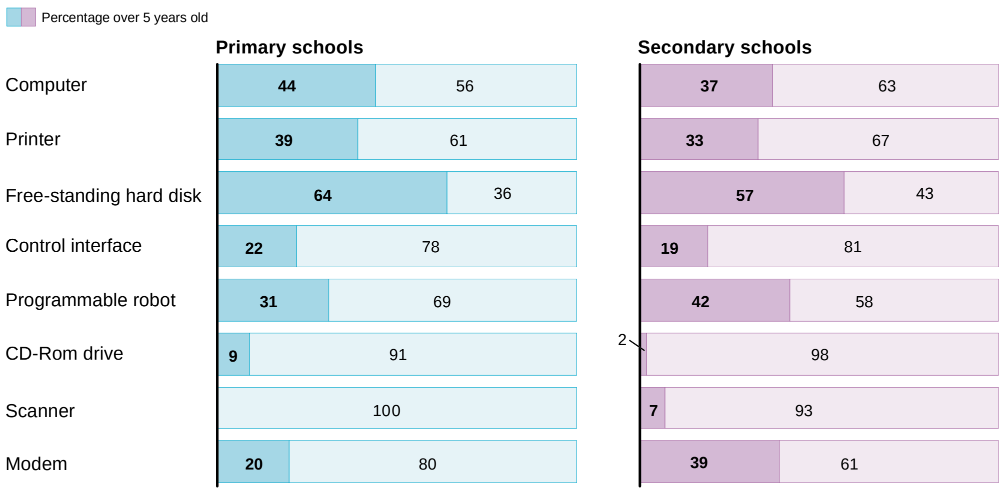


* England only
Source: *Survey of Information Technology in Schools*, Government Statistical Service, February 1995

Furthermore, many machines are fast becoming obsolete and incapable of running the latest software. About 40 percent of computers in schools were over five years old in 1993–94 (the latest year for which published figures are available at the time of writing) and, given schools' understandable reluctance to throw equipment away, the problem has probably worsened since. Many businesses would write off and replace equipment of this age (Exhibit 8).

The second limitation is the restricted practical guidance that teachers receive on how

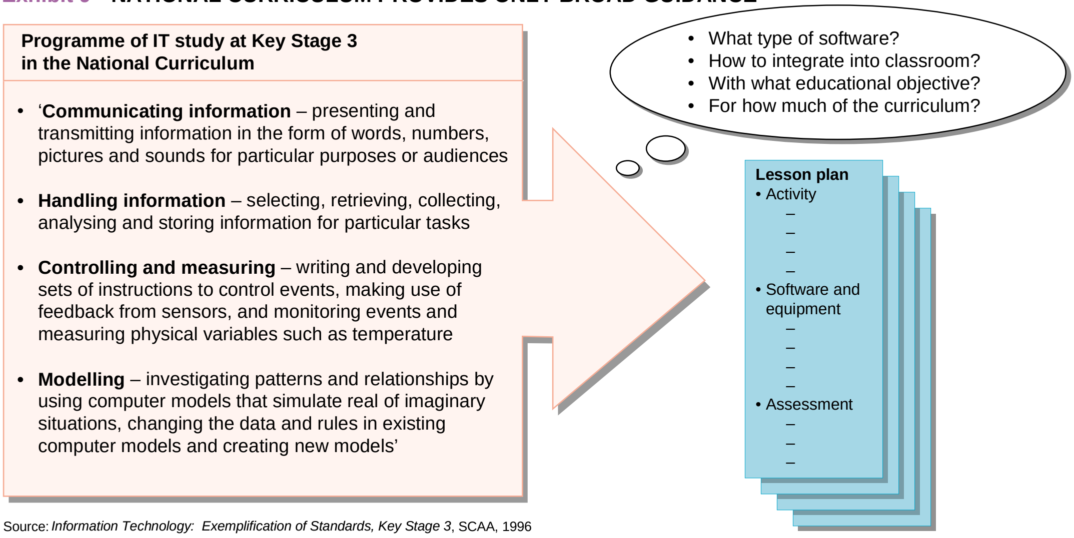
Exhibit 8 AGE ANALYSIS OF HARDWARE IN SCHOOLS, 1993-94* EXAMPLES



* England only
Source: *Survey of Information Technology in Schools*, Government Statistical Service, February 1995

to use IT in the classroom. The National Curriculum requires that IT be taught as a subject in its own right to all age groups – from ages five to 16 – and that it be used in the teaching of other subjects. But such requirements are described at too conceptual a level. The stipulations for key stage 3 refer broadly to 'communicating and handling information', for example, and to 'controlling, measuring and modeling'. There is little guidance on how teachers should interpret these requirements, or on which types of software they should use and what sort of teaching approach they should take (Exhibit 9).

Exhibit 9 **NATIONAL CURRICULUM PROVIDES ONLY BROAD GUIDANCE**



Source: *Information Technology: Exemplification of Standards, Key Stage 3*, SCAA, 1996

It is not altogether surprising therefore that today's results are mixed. Although research commissioned by the Department of Education in the early 1990s found that IT contributed significantly to student learning in mathematics, primary-level English and secondary-level geography, in other areas the impact has ranged from neutral to negative. Moreover, the extent to which IT is used as a tool in teaching other subjects varies enormously between subjects – with mathematics, technology, computer science and English the front runners – and between schools, with some secondary schools using IT frequently and some not at all. Again, many of these differences reflect varying policies between schools and between education authorities.

THE CHALLENGES AND OPPORTUNITIES

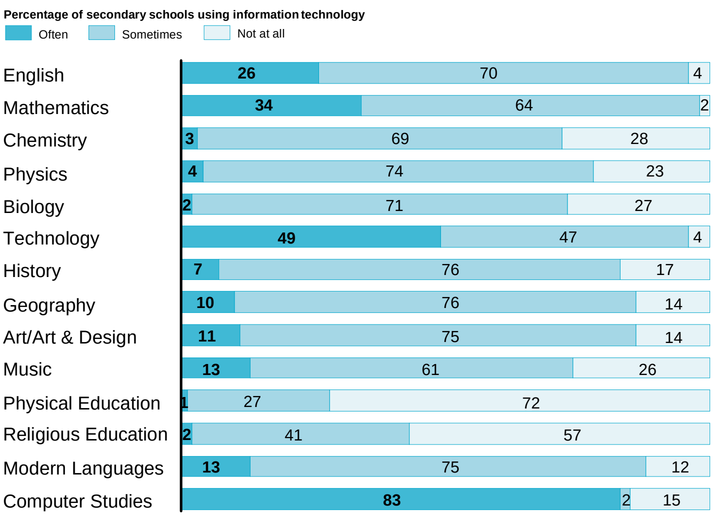
Yet it would be wrong to conclude from today's results that IT has a limited role to play in the future education of children. It would indeed be surprising if education proved to be isolated from technologies that have already had a fundamental impact upon business, and which are gathering pace in the home. Instead, the reasons for today's limited successes are the lack of clear educational objectives for IT, and the fact that many of the initiatives of the past 15 years have focused on getting hardware into schools while overlooking some issues that are critical if that hardware is to improve the way children learn. A more fully integrated approach is required. This need not imply a massive, centrally funded initiative – the fact that schools and education authorities have voluntarily raised their discretionary expenditure on IT in schools by a factor of six over the past decade suggests much of the necessary momentum and willingness is already there. Instead, what is needed is a series of smaller, but coordinated, initiatives to ensure this momentum is channeled most effectively, and to encourage a more consistent national approach.

The first challenge: To take a broader vision

Many schools have concentrated on applying basic IT tools across a limited range of subjects – spreadsheets for calculations in mathematics, for example, or wordprocessing in English. In 1993–94, a third of secondary schools used IT frequently in mathematics and a quarter in English. In other, non-technical, subject areas, however, schools used IT much less extensively. The same year, only 13 percent of secondary schools used it frequently in music and modern languages, 3 percent in chemistry and 2 percent in biology (Exhibit 10).

But the possibilities now are broader. Content-rich software, such as encyclopaedias or Internet sites that aggregate information, can be used to enhance the teaching of subjects such as geography and history. New types of interactive software – integrated learning systems, for example, which offer pre-programmed interactive courseware to enable children to learn at their own pace, and packaged

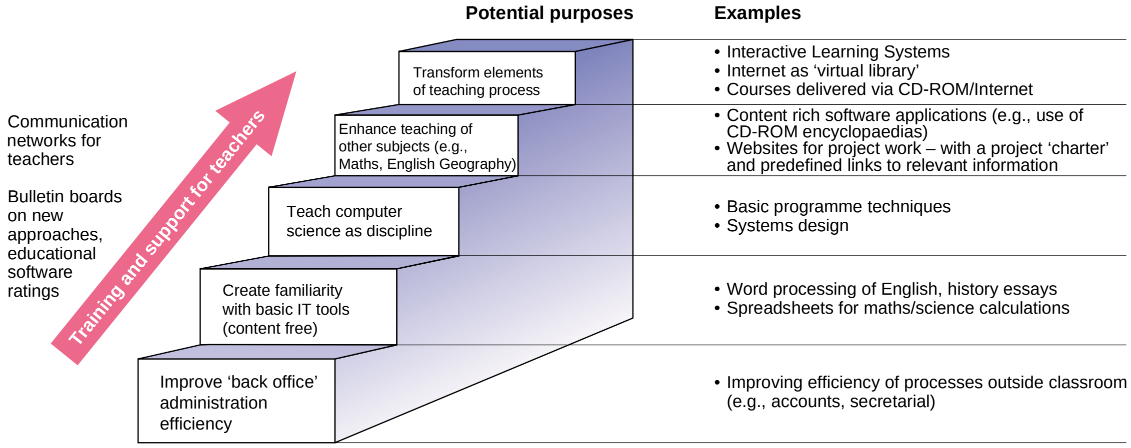
Exhibit 10 AREAS OF CURRICULUM USING INFORMATION TECHNOLOGY: SECONDARY SCHOOLS, 1993-94*



* England only, based on a representative sample of 510 schools
Source: *Survey of Information Technology in Schools*, Government Statistical Service, February 1995

interactive tuition courses in modern languages – can transform certain elements of learning. And in addition to their more traditional use in administration, computers linked to the Internet can provide teachers with support and training, by enabling them to communicate with one another via e-mail and electronic bulletin boards, and across educational Web sites (Exhibit 11).

Exhibit 11 THE 'STAIRCASE' OF POSSIBILITIES FOR IT IN SCHOOLS

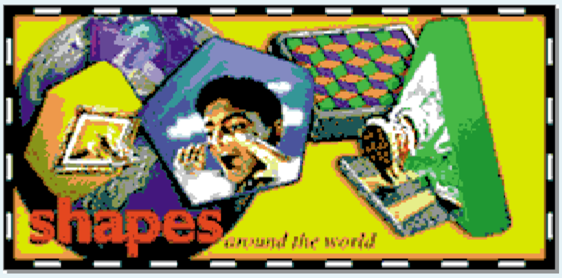


A Shapes Around the World project designed to teach basic geometry illustrates just one possibility. It gives children of eight and above access to an Internet site that takes them through a geometry 'adventure'. After a series of questions about the names and characteristics of basic shapes, each class is assigned an unknown 'geoshape', pieces of which are revealed as they proceed through the project. At the end of the journey, children can publish their own work in the Hall of Shapes, view the work of other children in classes around the world, and discuss their findings with one another (Exhibit 12).

Another project for a similar age group involves studying the solar system as part of a science class. Here, children use the Internet to reach a broader range of information and ideas than has been possible before. Working in pairs, they can search for information about, say, the Sun, and have access to astronomy sites with text, pictures and sound. Each pair downloads the relevant information, including documents on solar system data, and incorporates it into a final report (Exhibit 13).

Both examples relate to group work. But IT can also help individuals by allowing them to proceed as quickly as they are able and to gain instant (and private) feedback on how they are doing. Integrated learning systems are being developed by US and UK companies to take a child through a programme of interactive

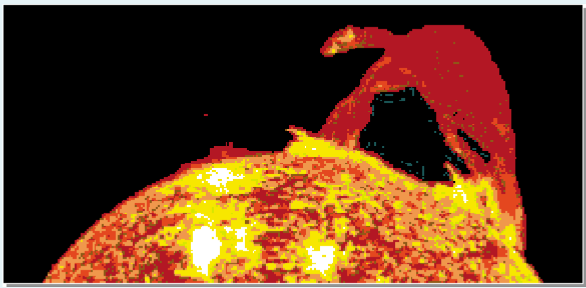
Exhibit 12 ENHANCING TEACHING OF OTHER SUBJECTS – MATHS EXAMPLE



- 'Shapes around the world' - an on-line project exploring polygons and tessellations, estimated to take between 3 and 6 hours
- Four component sites, plus links to other Internet resources
  - ***Geometry adventure*** " guides students through questions regarding names and types of shapes exploring their properties
  - A "***Geoshape*** " is assigned to each class, and pieces are revealed as children progress through the Geometry Adventure. Children can also view other classes' progress and write about the properties of their shape in "The Big Picture"
  - The "***Hall of Shapes*** " displays the Big Picture reports completed by classes around the world
  - Students can discuss shapes around the world with other classes in "***Talk Shapes***"

Source: www.rmplc.co.uk/eduweb/sites/wickham/topics/nineplnt.html; www.ccnet.com/success/shapes_preview/shp_overview.html

Exhibit 13 ENHANCING TEACHING OF OTHER SUBJECTS – SCIENCE EXAMPLE



- Working in pairs, children wrote down the target research (e.g., the Sun)
- One child searched for information on the Internet the other recorded how they navigated
- Pupils logged onto the school's LINK page, selecting "Yahoo" Internet search tool
- Entering "planets" as the search phrase yielded a variety of sites, including "The Nine Planets", described as a multimedia tour of the solar system with pictures, text and sound
- After exploring "The Sun" link on "The Nine Planets" site, they downloaded two documents on solar system data. They then logged off, having spent about 20 minutes on-line
- Each pair wrote a report about the lesson and displayed it with the pictures and documents they had printed out

Source: www.rmplc.co.uk/eduweb/sites/wickham/topics/nineplnt.html; www.ccnet.com/success/shapes_preview/shp_overview.html

learning that addresses basic skills such as mathematical concepts or grammatical constructions and relates them to real-life contexts (Exhibits 14 and 15).

These packages include systems that track and report progress, enabling teachers to focus on children who most need attention (Exhibit 16). An NCET-sponsored trial of such systems in 1994 concluded that they resulted in significant improvements in key stages 2 and 3 and that these gains were sustained over at least

Exhibit 14 **INTEGRATED LEARNING SYSTEMS - ADDRESSING BASIC SKILLS**

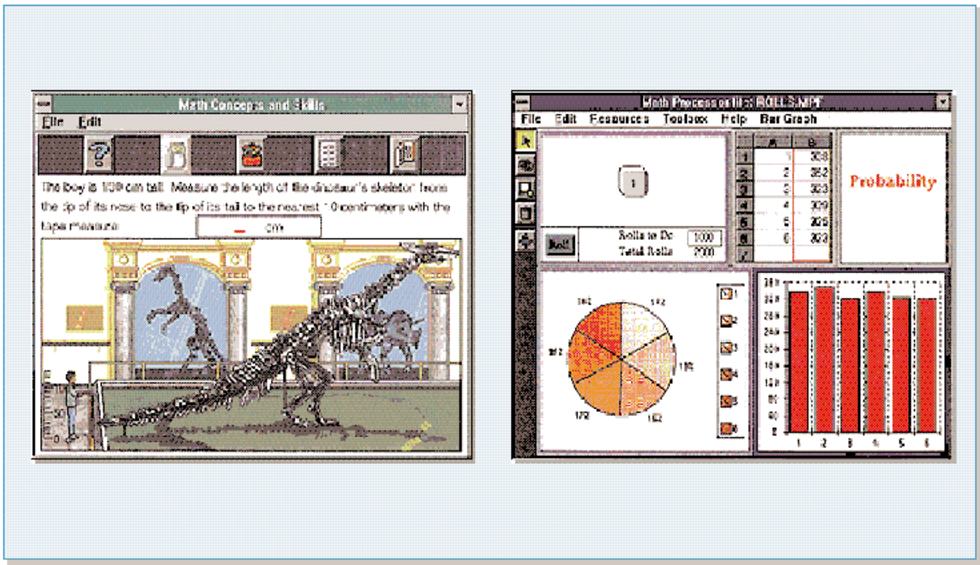
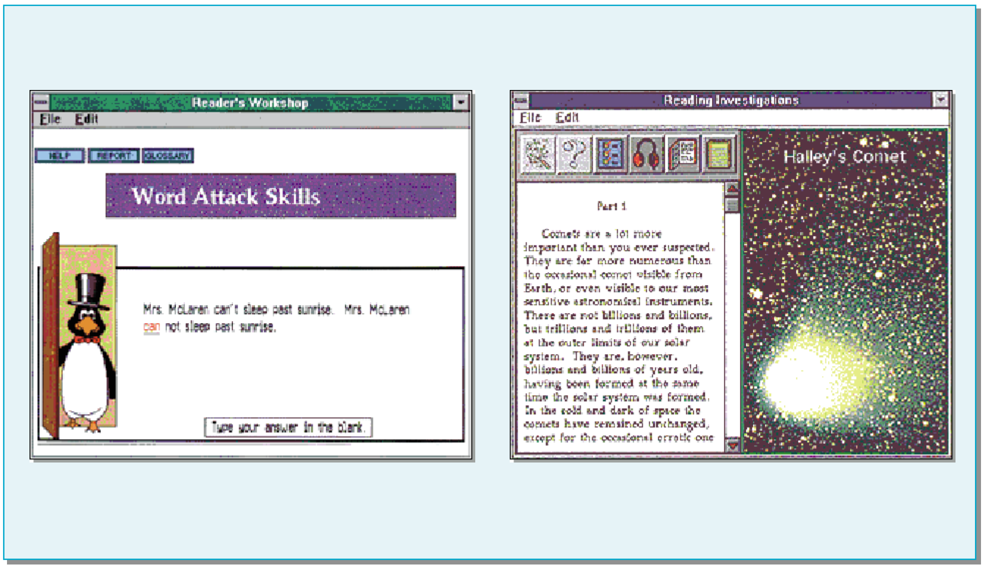


Exhibit 15 **INTEGRATED LEARNING SYSTEMS - COURSES USING REAL LIFE CONTEXTS**

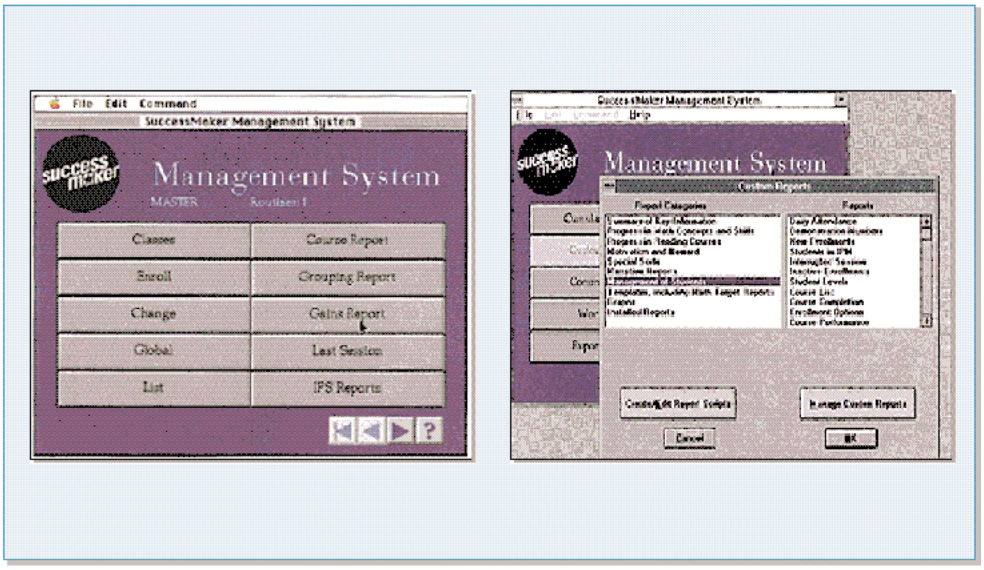


12 to 18 months. The systems were particularly beneficial in raising the basic numeracy of the least able children, but also helped the most able. There is some, more limited, evidence that this type of system can also improve literacy.

The second challenge: To prepare children for the future

It is essential that children be prepared for the conditions they will encounter in the future. Over the past decade, computing within the workplace has grown to the extent that the personal computer

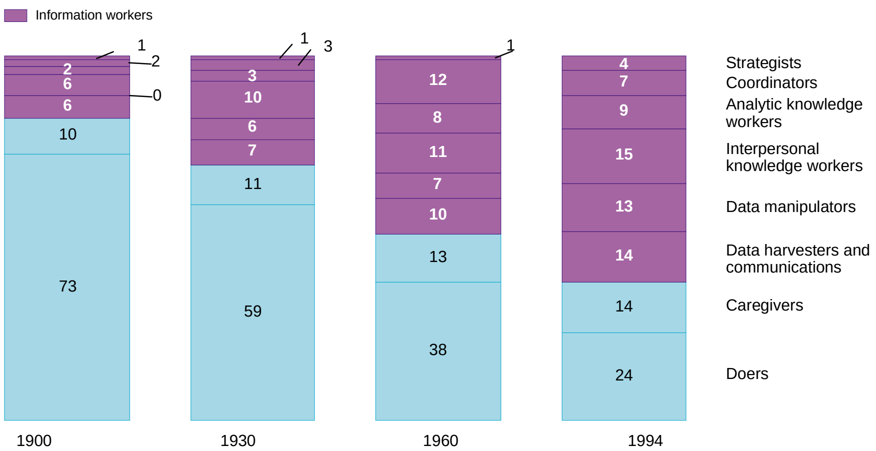
Exhibit 16 **INTEGRATED LEARNING SYSTEMS - PROGRESS TRACKING SYSTEMS**



is now an essential business tool. In the US, information-based activities account for 60 percent of employment, in line with the growth of the service economy. Yet many children leave school with only a rudimentary appreciation of IT, and in particular of the new possibilities fast emerging. While home computing will go a long way towards bridging this gap, there will still be a significant number of children whose only opportunity to use computers will occur at school or elsewhere in the community (Exhibit 17).

Exhibit 17 **THE NUMBER OF INFORMATION WORKERS IS GROWING**

Percent employment

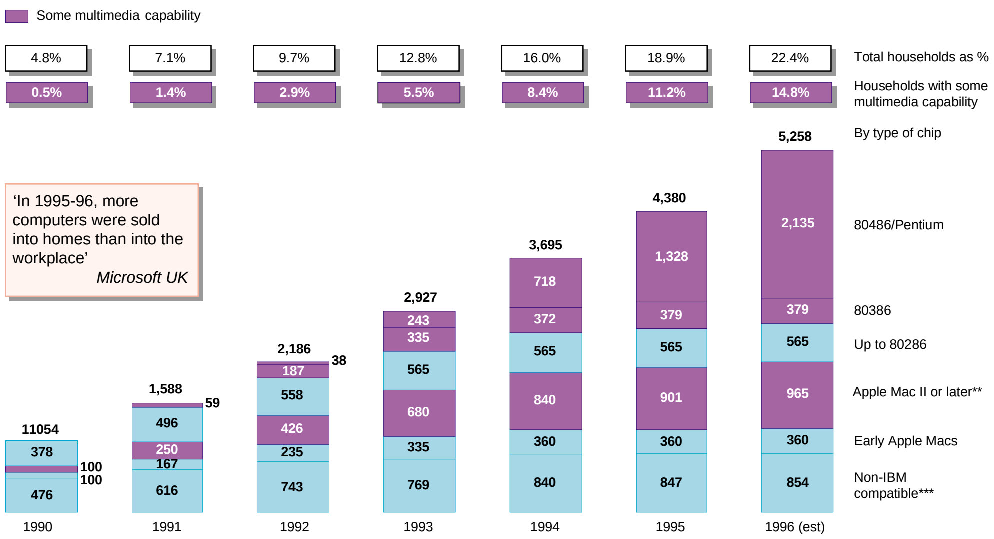


Source: Bureau of the Census; Bureau of Labor Statistics; McKinsey analysis

New opportunities: Home computers

Until now, the main thrust of policy on IT in education has been directed at the traditional place of learning – the school. Yet the rapid growth of computers in the home opens up possibilities to extend learning beyond the classroom. Ignoring machines purchased before 1989, there are now just over 5 million home computers, representing 22 percent of UK households. Of these, about two-thirds have relatively fast processors, equivalent to the Intel 386 chip or higher (Exhibit 18).

Exhibit 18 RAPID GROWTH OF INCREASINGLY SOPHISTICATED HOME COMPUTERS*

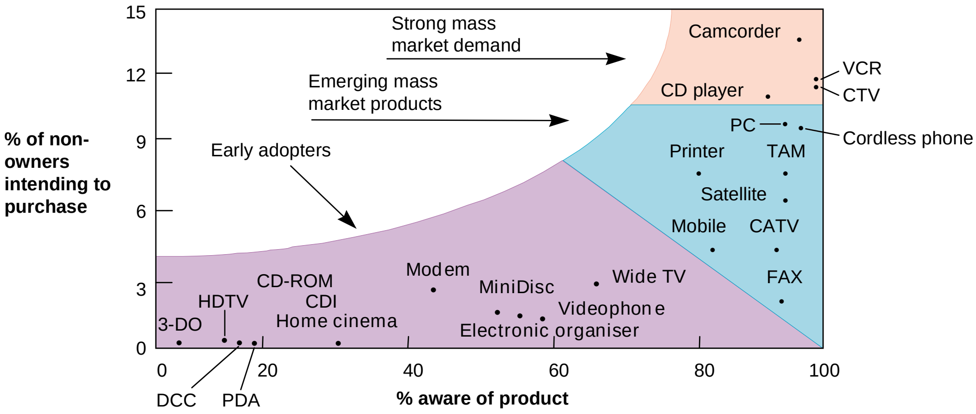


* Excludes pre-1998 machines
** All Macs with 68030 chips (LC II plus) or 68020 with upgraded RAM
*** Includes Acorn, Amstrad word processors, Commodore 64 etc
Source: Dataquest; interviews

The growth in home computers is likely to accelerate. Market research reveals that a high proportion of non-owners intend to purchase one in the near future, suggesting that the personal computer could soon become a mass-market item, in the same way as have CD players and telephone answering machines (Exhibit 19).

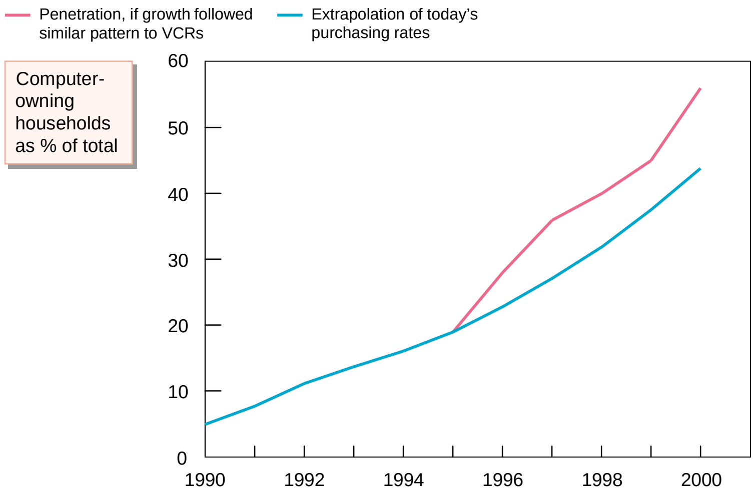
An extrapolation of the number of computers being sold to homes indicates that by 2000–1, about 45 percent of the population might have one. If growth in the home computer market followed the same pattern as the market for video cassette recorders, then the figure could be higher still, up to 50–55 percent of households (Exhibit 20).

Exhibit 19 PCs ON THE VERGE OF BECOMING MASS MARKET ITEMS



Source: BIS Strategic Decisions survey (1994); McKinsey analysis

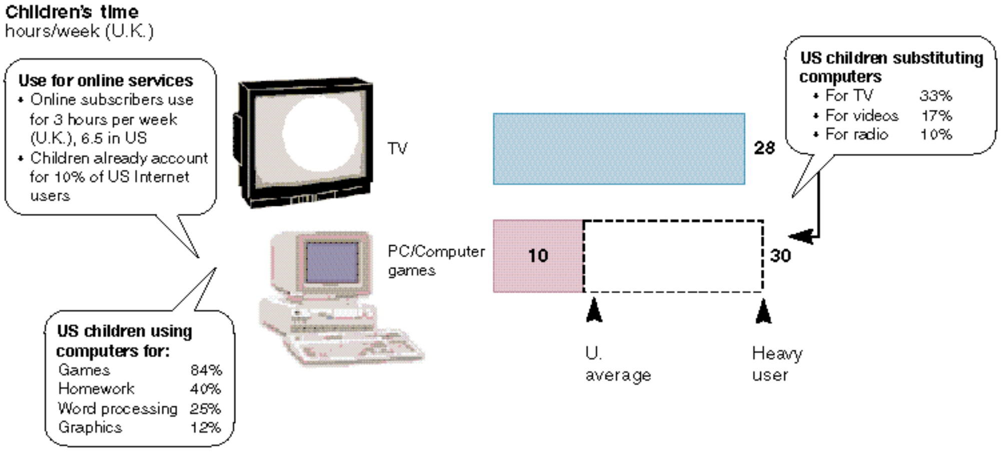
Exhibit 20 POTENTIAL GROWTH IN HOME COMPUTER PENETRATION



This growth represents a large, and largely untapped, educational opportunity. There is now real evidence of a shift in children's use of leisure time, in particular away from watching TV towards using computers and games devices. And children have a lot of discretionary time; the average child spends 28 hours a week watching television (comparable to the average over a whole year of 25 hours a week spent in a classroom or doing homework). If educationally effective software applications could capture even a small share of this shift, they could significantly boost the number of hours that children spend learning (Exhibit 21).

Yet educational applications account for only a small proportion of the consumer software market and there is little or no overlap between the types of software used in schools and the applications

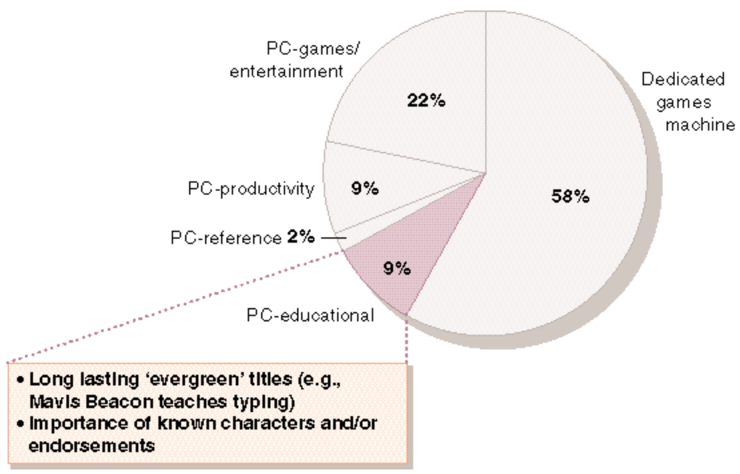
Exhibit 21 CHILDREN'S USE OF LEISURE TIME IS ALREADY SHIFTING



Source: Olivetti Personal Computers Home Market report, 1996; press clippings

Exhibit 22 EDUCATIONAL SOFTWARE - TODAY A MINORITY MARKET

US consumer software, 100% = US$5.3billion



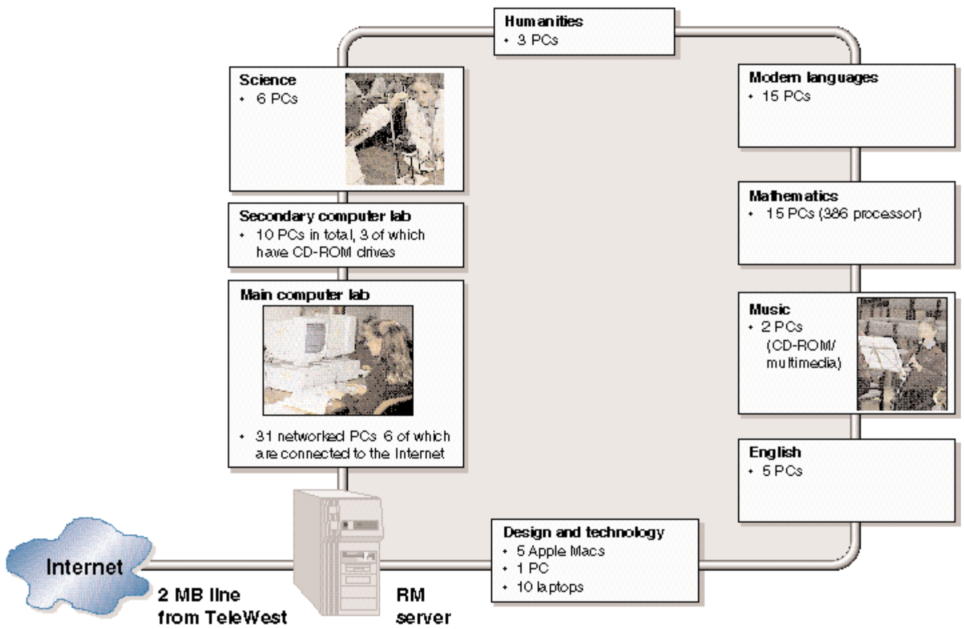
parents might buy. Paradoxically, parents often ask schools to recommend software or computers for children. All this suggests there is an opportunity to bridge the gap between computing at school and at home (Exhibit 22).

New opportunities: Computer networks

Probably the single most important event in computing in the past decade has been the realisation that the power and value of computing technology are greatly multiplied when individual machines are interconnected. Not only can networked machines communicate, but the network can also act as a platform for sharing information, ideas and software. Some form of local area network has already been installed in about half of secondary schools, primarily for efficiency reasons, the main data and software applications being held in a central file server on the network to which each pupil can gain access.

Particularly new is the idea that local networks can be linked to the outside world. The Internet and its World Wide Web have – as the result of innovations in graphical interface software or 'browsers' – become a common environment enabling networked computers to communicate with one another anywhere in the world. This opens up a range of educational possibilities. Software and other resources can be shared between schools, universities and external bodies. Teachers can pool approaches and ideas. And children can have access to information and resources they could not reach before, such as pictures direct from NASA during a physics lesson. They can also use the new medium to communicate via e-mail, with one another and with the outside. Although many UK schools are reported to have Internet access, for the vast majority this is limited to one or two machines. Some schools, however, are experimenting with new methods of networked learning, in which their local area network is itself connected to the Internet, allowing many machines simultaneous access to the outside world. A trial at the Invicta Grammar School for girls in Kent is an example (Exhibit 23).

Exhibit 23 **INVICTA GRAMMAR SCHOOL - AN EXAMPLE OF NETWORKED LEARNING**



Here, over 30 computers are clustered in a laboratory, at least half of which can have simultaneous access to the Internet. Further machines are distributed throughout the school in small subject clusters – including science, design and technology, modern languages, mathematics, music and English – and are interlinked via the school's local area network. Access to the outside is via a high-capacity line capable of carrying 2 million 'bits' of information a second, provided by the local cable company.

This, and similar experiments, illustrate an extraordinary range of possibilities. In areas such as poetry and art, children are able to publish examples of their own work and see the work of others. In science, the school has assembled a list of links to external resources such as the Natural History Museum, the Science Museum and ecology and astronomy sites. In German classes children practise the language by exchanging e-mails with students overseas (Exhibit 24).

Exhibit 24 EXAMPLES OF ACTIVITIES AT INVICTA GRAMMAR SCHOOL

ENGLISH – PUBLISHING POETRY

FOOLED by Donna Frith Year 11

"I'm going away" he said to me,
And reached over to squeeze my hand.
My throat clammed up, eyes filled up,
Only noise was the supporting band.

He stood up, kissed me sweet,
Said he loved me with his goodbyes.
My eyes overflown, left on my own,
Believing his stupid lies

SCIENCE – LINKING TO EXTERNAL RESOURCES

- Breast Cancer Screening
- Earth Viewer
- Ecology Channel News and Information
- Educational Resources
- Hubble Highlights
- Gene Web – news and views on modern Genetics
- LBNL ELSI Home Page – Ethical, Legal and Social issues in Science
- Natural History Museum
- New Scientist
- The Nine Planets – A Multimedia Tour of the Solar System
- Index of the Science Museum WWW Pages
- Your Chromosomes

GERMAN - COMMUNICATING WITH FOREIGN STUDENTS

The course is based on 'Gute Reise 1&2'. Students learn the basic language necessary in order to communicate in a German speaking environment in situations they are likely to encounter as young tourists.

In their lessons students meet a wide range of learning experiences including role-play, drama, letter writing, information exchange via E-mail and many others.

ART – PUBLISHING STUDENTS WORK

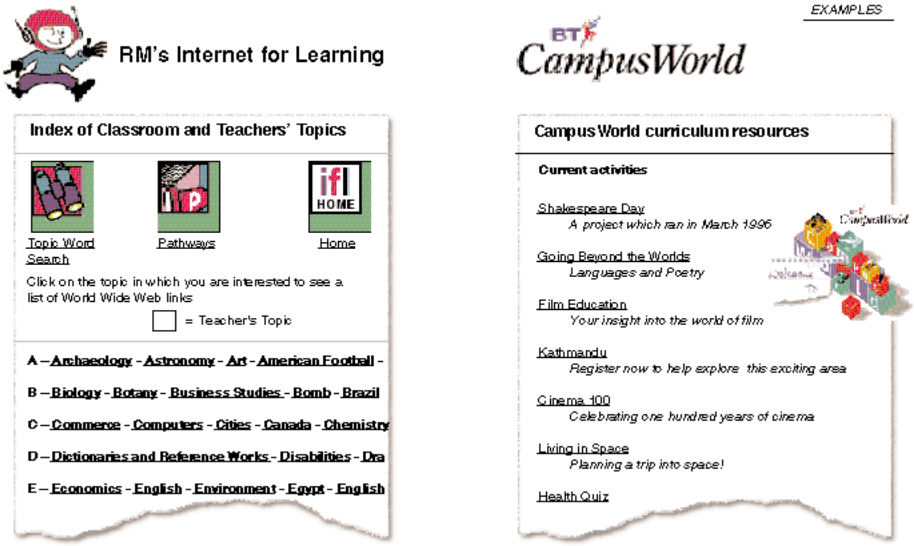
Kelly Cunningham Year 8

Source: www.rmplc.co.uk/eduweb/sites/invicta

The fast-growing range of educational resources includes BT's CampusWorld on-line service, which contains information and organised project work. To guide teachers and pupils around the expanding range of resources, indexes are being developed. RM, for example, has an alphabetical index within its own web site called Internet for Learning (Exhibit 25).

Exhibit 25 EDUCATIONAL RESOURCES ON THE INTERNET ARE GROWING RAPIDLY

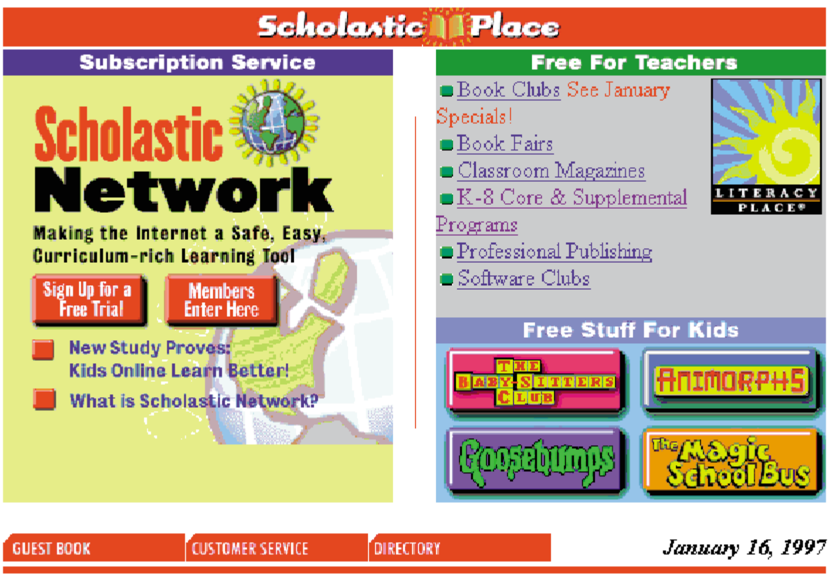
EXAMPLES



Source: http://ifl.rmplc.co.uk/bin/$webdbc.exe/links/qryncsubj/select/&/links/tchindex.htx?; http://www.campus.bt.com.Campus World

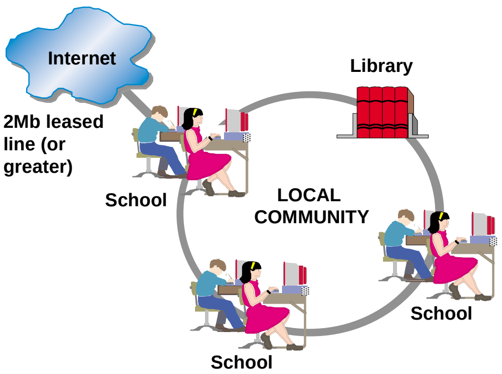
The US company Scholastic has also developed a variety of resources on the Internet, with an emphasis not just on children, but on serving teachers themselves as a 'community of interest'. Scholastic enables children to play educational games such as spelling and mathematics puzzles, publish essays, poems and artwork, and work through predefined projects. Teachers can participate in hosted on-line discussions on issues such as 'raising student achievement in comprehension, communication and presentation skills' and 'integrating technology' (Exhibit 26).

Exhibit 26 USING THE INTERNET AS A VEHICLE FOR TEACHERS: SCHOLASTIC PLACE



As well as enabling content and ideas to be shared, external connections to the Internet can also help the hardware installed within an entire community to be used more efficiently. Some have proposed a model for 'learning within the community', whereby computers not just in schools but also in public buildings such as libraries, and potentially in the home, all have access to a common set of networked resources. Not only would this enable schools within a given region to share content, it would also allow children, teachers and parents access to the same resources seamlessly from various locations, some of which could remain open outside school hours. A pilot scheme is already under way near Reading (Exhibit 27).

Exhibit 27 A MODEL FOR COMMUNITY LEARNING AND TRAINING



Learning in the community

- Parents / local businesses use facilities in schools out of hours
- Charges for parental/business use reinvested in IT provision

Training and support (Microsoft proposal)

- Currently establishing 25 community centres to 'train the trainers'
- Training courses for teachers in IT basics using (Microsoft's) network of value added resellers and community centres
- Training vouchers distributed with PCs
- Accreditation provided once courses passed

Concept

- High speed Internet connections, linking PCs in schools and community facilities
- Remote management of network
- Pilot example underway (Highdown, Ashmead and Meadway schools – Reading; Wokingham library)

THE ISSUES TO BE RESOLVED

While much has been done over the past decade to help promulgate the effective use of IT in education, the opportunities for the average schoolchild today fall well short of the full range of possibilities. However, all the uses outlined in this report can be seen in practice, albeit often as isolated examples in schools where a head, a group of teachers or a local authority has been particularly innovative.

For IT's full educational promise to be realised, there are certain issues that need to be addressed. In particular there needs to be:

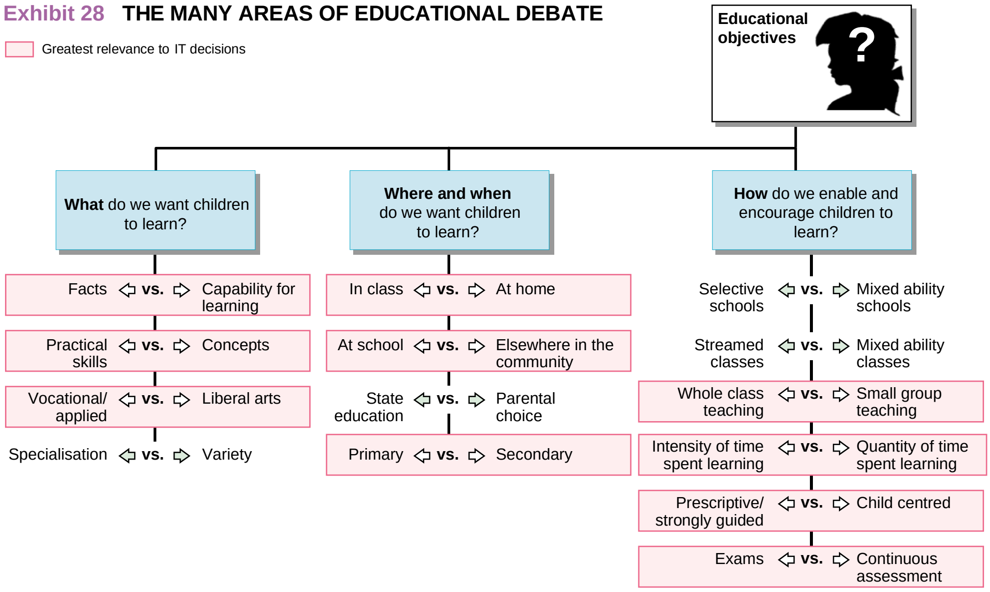
- ***More clarity over educational objectives for IT*** and how they relate to any one educational philosophy.
- ***Improved training and support for teachers*** and a more coherent body of software that recognisably meets certain standards.
- ***More substantial software packages*** that address a broader cross-section of the curriculum, but which the fragmented software development industry has so far been unable to develop.
- ***Cheaper connections to the Internet*** if schools are to take advantage of opportunities offered by external networking.
- ***More up-to-date hardware.***

The need to clarify IT's underlying objectives

The wide variations in how IT has been applied in schools partly reflects the lack of a common set of views on the educational benefits sought. This underlines the importance of clearer, more integrated objectives for IT. One complication is that the debate on education itself is in flux, with varying philosophies on:

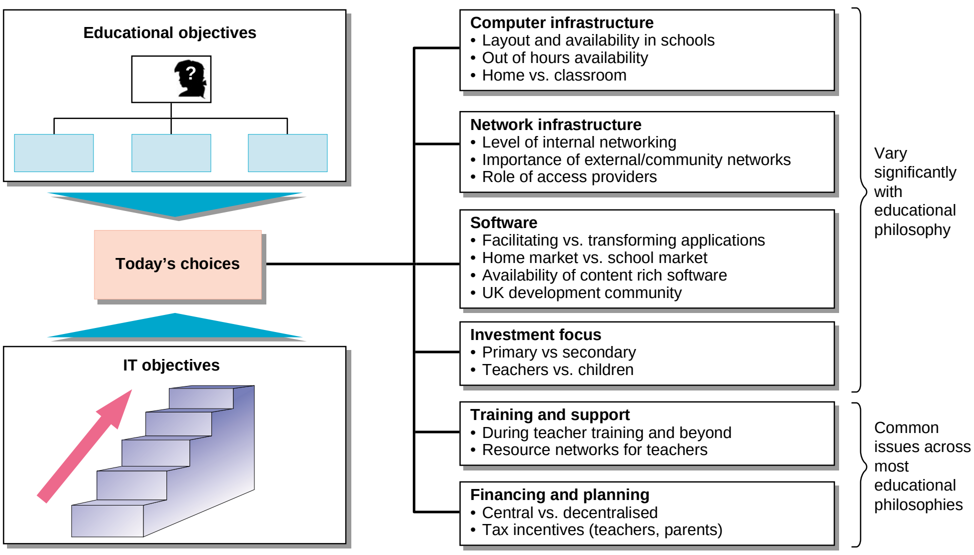
- ***What we want children to learn,*** and whether the emphasis should be on learning facts and vocational or practical skills, or on capabilities and concepts.
- ***Where learning should take place,*** and the relative importance of the classroom, the school and the community, and the correct balance of resources between primary and secondary education.
- ***How children can be enabled and encouraged to learn.*** This covers the debates over selection and streaming versus mixed-ability classes; over large and small groups; the intensity and amount of time spent learning; the balance between prescriptive and 'child-centred' teaching; and methods of assessment (Exhibit 28).

Exhibit 28 THE MANY AREAS OF EDUCATIONAL DEBATE



Whichever philosophy one believes in, the connection has to be made between educational objectives and the objectives for IT. Different views on where children should be taught affect where computers are provided – whether in the classroom, elsewhere in the community or at home – and hence the importance of external networking. Likewise, the balance to be struck between children learning facts and practical skills versus broader capabilities affects which software is chosen. Views of how children should learn (in whole classes, small groups or as individuals) and how they should be taught (by prescriptive or child-centred methods) affect the precise mix of network infrastructure and software (Exhibit 29).

Exhibit 29 POLICY OPTIONS DEPEND UPON EDUCATIONAL OBJECTIVES



The need to train and support teachers

There is evidence that many teachers lack the training, support, communications and therefore proficiency to be fully effective in the use of IT. Almost everyone we interviewed highlighted this as one of the most important issues (Exhibit 30).

Exhibit 30 **UNIVERSAL SUPPORT FOR BETTER TEACHER TRAINING**

"The single biggest barrier to educational progress is the teacher's inability to find out what's available to use and how to use it. This is part of a general issue, which IT has highlighted."

Computer Company CEO

"There is a dramatic need for teacher training. You can have 90% of teachers in a school never using the machine - we've got five years of catching up to do."

Training Agency Head

"We believe that increased training is essential. We are in the process of setting up 25 community training centres to 'train the trainers' – including teachers.

Head of Education, software company

"We first trained the faculty heads in the school. Once they understand the potential for IT and how to use it, they can cascade the training further down within subject groups. This, and enthusiasm from students creates the critical momentum needed"

Secondary School Head

"The problem is teachers don't have time for continuous learning in the day to day classroom environment. Maybe we need a 'gold star' accreditation system for teachers – like learning the piano"

Primary School Headmaster

"Only 40% of teachers can use IT competently. Assuming around 20% of teachers are technophobes, this leaves another 40% of teachers needing to be trained"

Government Agency

Judging by research carried out in the US, teachers need to pass through five stages in order to use computers in the classroom to best effect. At the 'entry' point, at which teachers have access to computers but limited experience of using them, many – not surprisingly – struggle. At the second, 'adoption', point, which typically requires 30 or more hours of training, teachers succeed in using the technology, but at a fairly basic level. As they reach the 'adaptation' stage, requiring a further 15 hours of more of training and several months of experience, they start to realise IT's potential across a number of applications. By the time teachers have received 60 or more hours of training, and up to two years' experience, they are usually fully comfortable with the technology and able to integrate it into the curriculum. When they have gained several more years' experience, they often start to devise their own approaches using technology as a flexible tool (Exhibit 31).

However, most teachers leaving teacher training colleges have received only 20–30 hours of IT tuition. Because time is short, much of this focuses on the basics and on teaching IT as a subject in its own right, as opposed to providing guidance on how to use it as a broader teaching tool. Teachers often receive

Exhibit 31 TECHNOLOGY SKILL STAGES FOR TEACHERS

	Description	Professional development needed*
Entry	Teachers struggle to cope with technology and new learning environment	–
Adoption	Teacher moves from initial struggle to successful use of technology at a basic level	• 30 hours training
Adaptation	Teacher moves from basic use to discovery of potential in a variety of applications, and can perform basic troubleshooting	• 45+ hours training • 3 months experience
Appropriation	Teacher has mastery over the technology and can use it to accomplish a variety of instructional and classroom management goals	• 60+ hours training • 2 years experience
Invention	Teacher actively develops entirely new learning techniques that utilise technology as a flexible tool	• 80+ hours training • 4-5 years experience

* Required times are cumulative
Source: *Connecting schools to the Information Superhighway*, NIIAC report, May 1996; interviews

little or no subsequent training – which, given the pace at which IT develops, means their knowledge soon becomes outdated. And because there is no mechanism by which teachers can continuously learn and communicate with one another, it is hard – except perhaps within the largest schools – for teachers to share experience and ideas.

Fragmented software supply

Software is something of a paradox. On the one hand it could be argued that the UK educational software industry is vibrant, with over 200 developers producing tailor-made packages. On the other the problem is that almost all of them are very small – with average annual turnover of less than £100,000 – and lack the resources to develop more substantial products that could be integrated across a broader cross-section of the curriculum. One reason for the fragmentation is the hardware policy of the 1980s. Acorn's early lead, coupled with the support it enjoyed in schools, led to it becoming the dominant machine early in the decade. Even in the face of competition from machines operating Microsoft Windows, Acorn has retained about 70 percent of the primary school market and 25 percent of secondary schools. Other companies have grown alongside Acorn, including most of the UK's educational software developers, support groups and distributors.

But because Acorn's machines use a proprietary operating system which has been confined largely to the UK, the software companies who develop for this system have in effect been excluded from wider markets. Meanwhile other systems have gone on to achieve higher worldwide sales. Windows-based machines dominate the global market for desktop business in computing and Apple Macintosh machines have significant sales in US schools. Because they lack access to global markets, UK software developers cannot justify substantial investments in development and focus instead on smaller, niche applications that are simpler to develop. There are now over 170 subject-specific educational titles produced by Xemplar (Acorn's joint venture with Apple in education). About half that number of titles are distributed by RM for Windows machines. Some are off-the-shelf consumer or business packages not specifically developed for the education market (Exhibit 32). (This fragmentation is in marked contrast with the games software industry, in which the UK is a world leader. UK companies, which write software for machines sold internationally such as the Nintendo and Sega games consoles and the PC, now account for about 40 percent of the world market.)

Exhibit 32 COMPARISON OF EDUCATIONAL SOFTWARE OFFERINGS*

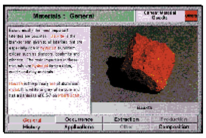
Xemplar (Acorn/Apple) Number of titles		Research Machines (RM) Number of titles**
30	Art and design/graphics	4
12	English/literacy	3
5	Modern languages	8
30	Mathematics	6
26	Science	33
27	Geography	12
33	History	18
9	Music	3

* Includes CD-ROM
** Does not include ILS
Source: RM software catalogue at www.rmplc.net/rmplc/rmd/software/index.htmf; Xemplar product catalogue

The upshot of all of this is that although there are a large number of educational software titles in this country, many overlap and address similar objectives such as basic numeracy or literacy. There are few, if any, integrated packages that cover a substantial portion of an entire syllabus such as GCSE mathematics, physics or French. And because there are many overlaps between packages, teachers (and parents) find it difficult to understand their relative merits. Unlike the area of conventional textbooks, in which a limited number of publications tend to be accepted as standard reference works which schools then distribute, there is no systematic method of rating software packages for their educational value (Exhibit 33).

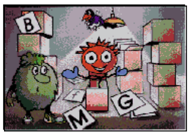
Exhibit 33 EDUCATIONAL SOFTWARE ONLY LOOSELY LINKED TO THE CURRICULUM

Science Series



- Multimedia reference library and science practical via animations
- Series of titles on science topics (e.g. materials)
- Teachers can customise the disc by selecting certain areas for pupils to study
- Winner of several awards, including BETT Gold 1994

"Max and the Machines"



- Designed to help develop reading skills for children aged between 4-7
- Contains set activities each of which has a specific learning purpose. Child progress is recorded and the difficulty levels adjusted automatically
- Best-selling primary title in 1995 and winner of many awards

"En Marcha"

- Multimedia resource to support Spanish teaching and speaking
- Allows users to browse through a series of images and animations, with vocabulary and context highlighted
- Winner of best educational CD-Rom in Britain in 1994

"Supermarket"

- Designed to teach basic numeracy skills
- Emphasises skill relevance by relating them to real-life situations
- Customisation features allow use across a wide age range
- Results can be saved for teacher review

BUT

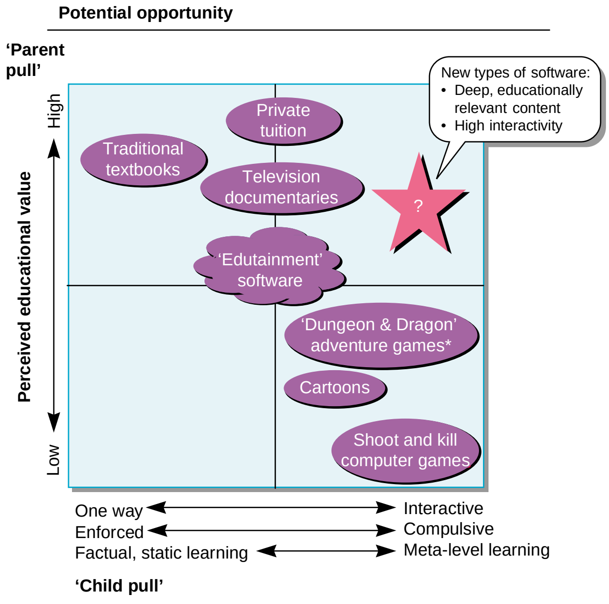
- Wide range of packages addressing similar learning objectives (e.g., basic literacy, numeracy)
- Few (if any) integrated packages covering entire syllabus
- No clear endorsement of particular packages as the educational standard (in contrast with standard "reference" textbooks)

Source: Software catalogues

The lack of a system of endorsement also affects the largely undeveloped market for educational software in the home. About 80 percent of consumer spending on software is on computer games, either the so-called 'twitch' and 'shoot-and-kill' games or the more reflective adventure games that guide players through an interactive series of riddles and puzzles. The most successful are those that capture children's imagination and drive compulsive behaviour (Exhibit 34).

Against this dimension of 'child pull', there are many other products which rely more on 'parent push'. The key to unlocking the educational software market for the home would be to develop applications that combine the two. Such applications would require a breadth of content that arouses and sustains children's curiosity, and which attracts parents by addressing the syllabus on which their children will ultimately be tested. But until there is a rating system, there are likely to be few such products. It is a vicious circle. Without a rating system, parents and teachers do not have the information to decide whether a program is genuinely educational or fits with the current syllabus. Then, because the flow of information and distribution is fragmented, it is hard for any excellent software that does emerge to develop a large market share, or to bridge the gap between school and home markets. And

Exhibit 34 POTENTIAL FOR EDUCATIONAL SOFTWARE IN THE HOME



without the prospect of a sizeable market, developers lack the economic incentive to reinvest and develop products with a broader content. (In the computer games market, by contrast, where there are clear market leaders, magazines fulfil the need for endorsement by deciding whether or not to recommend products to readers.)

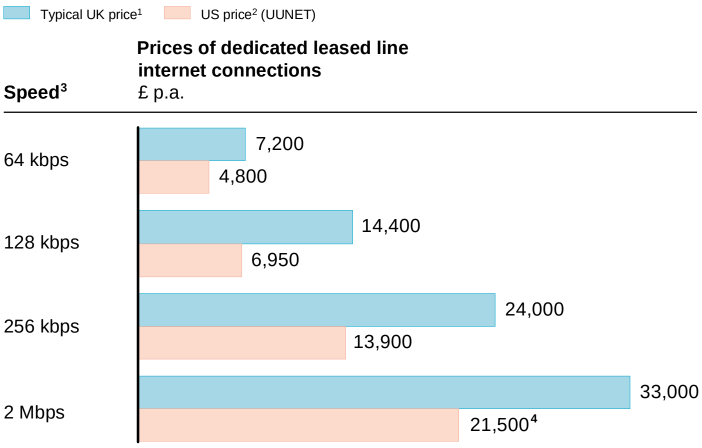
Developers which decide to enter these markets will need to evolve software for an operating system with a larger share of the worldwide education and home market than Acorn has, or in a platform-independent programming language such as JAVA.

The costs of joining the Internet

In the past, commercial pricing has left schools unable to take full advantage of the benefits of connecting computers to the outside world. In particular, they want to avoid tariff arrangements that charge a high variable rate according to the amount of external network capacity used, because they make budget planning uncertain.

The cost of even a relatively small capacity connection to the Internet of 64,000 bits per second (kbps), which could support eight computers simultaneously browsing the World Wide Web for text, plus moderately heavy graphics, would be around £7,000 a year at current commercial UK rates. For a high-capacity leased line offering a permanent connection of 2 Mbps, the figure would be £30,000 a year. Even £7,000 is a significant cost compared with the total budget of a moderately sized primary school; the higher end would be hard to afford for even the largest secondary school (Exhibit 35).

Exhibit 35 TYPICAL COMMERCIAL PRICES FOR EXTERNAL INTERNET ACCESS



1. Outside London area – leased line prices can be lower in 0171, 0181 areas. Excludes start-up fees
2. Based on one year commitment periods; excludes start up fees
3. A 64 kilobit per second connection will support 6-8 computers simultaneously browsing the World Wide Web for text and light graphics pages. Higher bandwidth needed for heavy graphics and audio
4. Burstable TI service (1.5Mbps) at 25% utilisation adjusted pro rata to 2 Mbps.

Source: Interviews

The need to modernise computer hardware

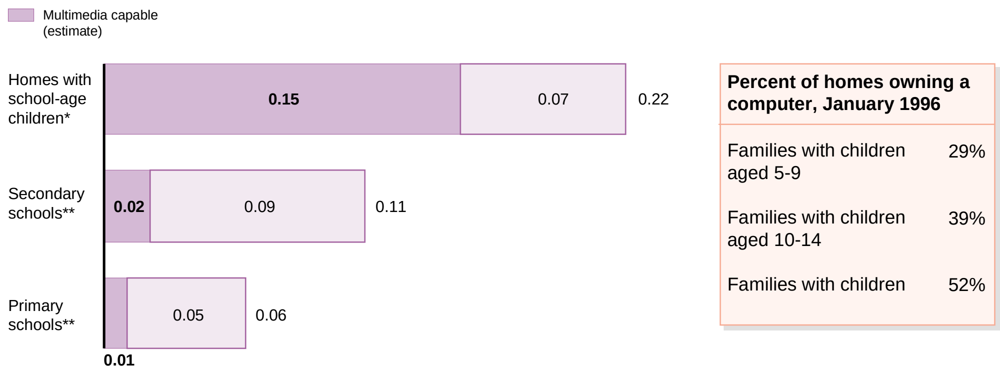
While the UK is reasonably well positioned in terms of the number of computers per child, the value of that installed base is limited, given that almost half of the machines are over five years old and that there are wide variations between regions and schools. The main thrust of policy on computers for schoolchildren should therefore be to upgrade machines that are incapable of running modern software.

The growth of computers in the home reinforces the importance of modernising hardware in schools. Most home machines have been bought in the past five years, and many have advanced processors. In addition, there are already twice as many home computers per child as there are computers per child in secondary schools, and four times as many as there are per child in primary schools (Exhibit 36).

This growth has several implications (Exhibit 37). First, schools will be under pressure to upgrade their machines and reduce the widening gap in performance between their equipment and machines bought for the home. Second, schools are likely to have growing influence over computing in homes as parents seek advice on what software and hardware to buy (although, as already

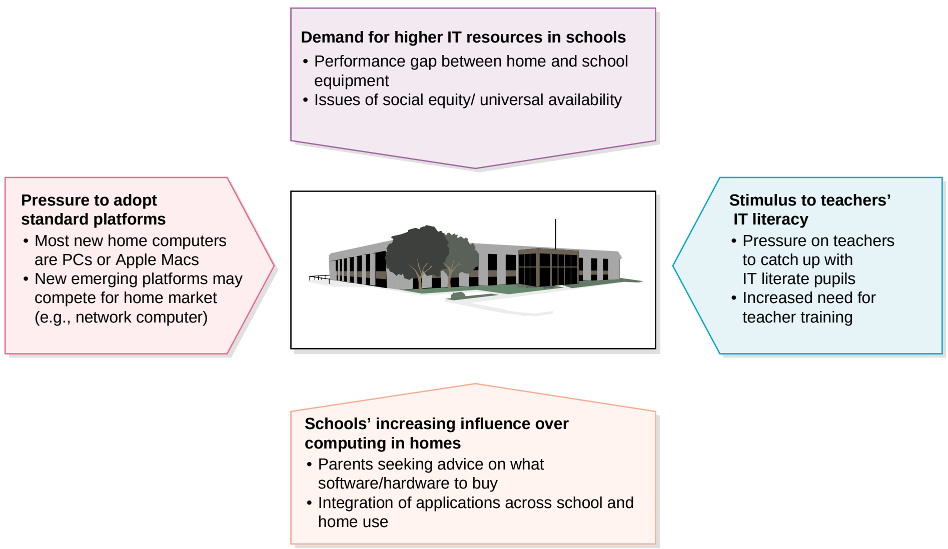
Exhibit 36 AVAILABILITY OF COMPUTERS IN HOMES EXCEEDS AVAILABILITY IN SCHOOLS

Number of computers per child



* Assumes 40% of homes with school-age children have a computer and that the same percentage of these are advanced as in total homes
** Assumes 12/90 computers in each UK primary/secondary school in 1996, 2/20 of which are multimedia capable
Source: DFEE statistics; Oliveth Personal Computers Home Entertainment Market Report, 1996; MINTEL

Exhibit 37 GROWTH IN HOME COMPUTING HAS IMPLICATIONS FOR SCHOOLS



stated, parents and teachers alike first need guidance on which software is really educational and how it fits with the curriculum).

Third, home computing will stimulate teachers to become more computer literate to keep up with their pupils, some of whom become familiar with technology at a remarkably early age. Fourth, schools will face pressure to buy computers compatible with those being sold into the mass market, most of which now run Microsoft or Apple operating systems. Given the uncertainties over the precise direction of computing, however, we would not advocate intervention in favour of particular hardware other than to encourage schools, where possible, to buy software that can be run on a range of hardware or which has been developed in fully portable languages.

THE ISSUES – HOW TO RESOLVE THEM

A centrally driven policy aimed simply at increasing the number of computers in schools would probably be an inappropriate way to address these issues, given that most school spending on IT is already decentralised and that many of the issues relate more to how the hardware is used than to the quantity of it. Instead, what is needed is a set of smaller, but co-ordinated, initiatives aligned around clearer objectives. Our ideas centre upon:

- Frameworks for clarifying the educational objectives for IT
- Engaging teachers
- Measures to improve software supply
- Tackling network costs
- Options for upgrading hardware

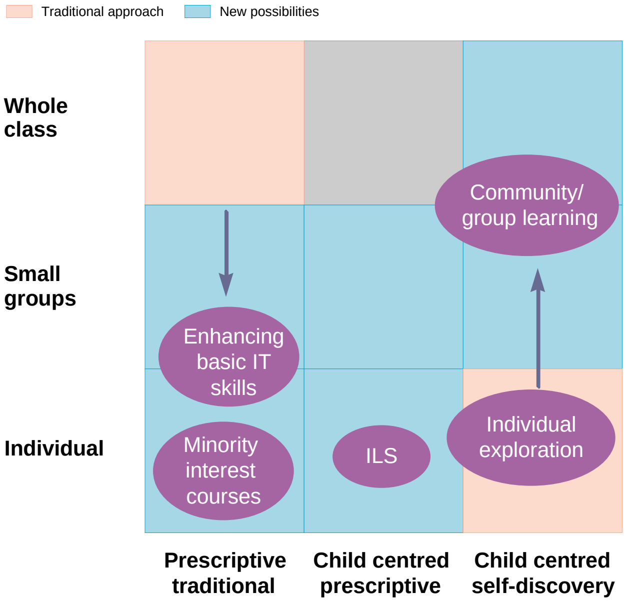
Clarifying the objectives

Whatever educational philosophy one espouses, IT can have an impact, although the precise application will vary. Take the issue of how children should learn. Traditionally the debate has been polarised between the prescriptive, traditional teaching of large groups or a whole class, and the child-centred teaching of small groups or individuals in which children are more directly responsible for their own progress. In traditional classrooms it has been hard to adopt prescriptive teaching methods for small groups because of the limited time a teacher can spend with each individual. Similarly, it is hard to envisage child-centred teaching being applied to larger groups if they lack a ready means of communicating and sharing information.

But IT opens up possibilities. Integrated learning systems, for example, allow each child to follow a prescriptive teaching programme at his or her own pace. Through networks, children can both explore new sources of information as individuals and work more effectively in large groups, on projects with other schools and institutions for example. IT could also change the economics of providing minority subjects. A course in, say, Greek that might not be viable in a small school could be encapsulated on a CD-ROM or the Internet (Exhibit 38).

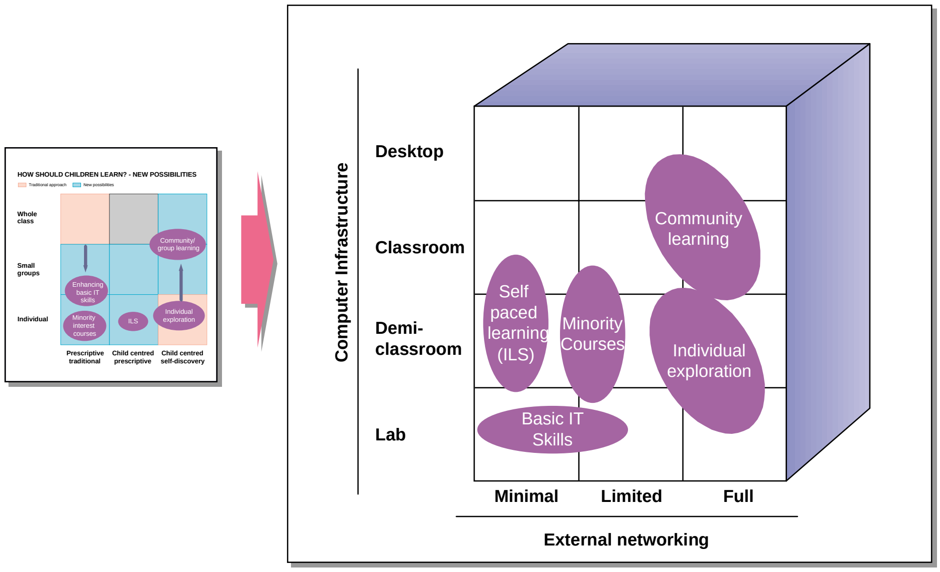
Decisions over teaching methods have implications for the types of infrastructure, networking and software needed. In general, external networks become more important as a school moves

Exhibit 38 HOW SHOULD CHILDREN LEARN? - NEW POSSIBILITIES



on from teaching IT as a basic skill towards using it as a tool to encourage learning as an individual or as a community (Exhibit 39).

Exhibit 39 RELATING TEACHING PHILOSOPHIES TO POLICY OPTIONS



Self-paced learning in the form of integrated learning systems may not need the same level of external networking, and can more easily be from computers that are clustered, either into small groups (with a number of computers in each classroom or every other classroom, for example), or into a central laboratory.

Engaging teachers

For teachers to become more comfortable with information technology and more proficient, three things need to happen. First, training must be strengthened, during teacher training and subsequently. Second, teachers need ready access to computers so they can learn in their own time and continually experiment, and third, they need ways to communicate so they can exchange ideas. Here, we set out our ideas for initiatives that are likely to be relatively inexpensive, but would go some way towards meeting these requirements.

As well as increasing the hours spent on IT during teachers' initial training, there are other ways in which they could gain the necessary grounding. Training colleges themselves could use IT as a tool to illustrate how to teach a non-technical subject such as geography or English. This could include field visits to showcase schools. Training colleges could also be equipped with enough computers to provide each student with access during training. (This is already a requirement of the Open University teacher training course, where students are equipped with a personal computer.)

Training also needs to continue throughout a teacher's career. It could be provided by commercial organisations that already offer training for businesses. There are a number of 'Baker Days' in the educational calendar designated for training, but no firm directions on how these should be used. One or more could be earmarked for IT training.

Several interviewees commented that teachers who have ready access to computers – particularly if it is their own machine – quickly become enthusiastic about the possibilities. It could also be an inexpensive means of training. Teachers with computers often experiment in their own time, reducing the need for more costly training during school hours. The Invicta Grammar School adopted a cascade approach to training in which faculty heads were trained first and given access to a laptop PC. Once proficient, they became responsible for training other department members. An NCET pilot scheme last year in which teachers in several schools were provided with laptops was successful. The teachers quickly became familiar with the technology, and used it to communicate with other teachers via e-mail and the Internet.

These examples point up the sense of giving teachers their own machines, either by providing them directly or by allowing teachers to deduct the cost of a machine they buy themselves against income tax, recognising that it will be used for educational purposes.

On the third issue of how teachers communicate, a simple way forward would be to establish a Web site with a series of bulletin boards. This would be particularly helpful if teachers had computers in their homes, since they would be using the network to learn during their own time. It could easily be combined with the earlier ideas on software for the Internet.

These measures will be effective, however, only if teachers are recognised for achieving a certain level of IT proficiency and assessed on that basis. At present, there is no direct recognition of this in OFSTED's assessment system.

Improving software supply

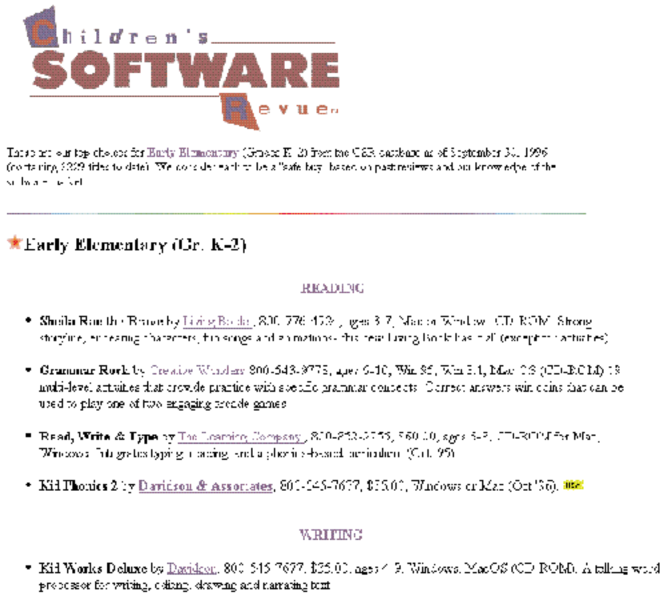
The number of UK educational software developers reflects the fact that this is a highly creative business in which it is hard to predict who might devise the most effective applications. Yet there are measures any government could take to stimulate the growth of a more substantial software base, with the resources to develop content-rich educational applications and to promote a flow of information that would help parents and teachers determine which are the most educational packages.

One reason why software companies are unable to invest more in development is that the schools market by itself is insufficient to justify it. Devising a modern application such as an integrated learning system can cost several million pounds, which is hard to recoup across a market of only some 30,000 schools. But if some of these applications could simultaneously be sold to the home market, the return would be substantially higher.

One way to bridge the gap between home and school markets would be to establish a comprehensive rating system. This could emulate a standard such as the 'Kite Mark', and would signify that the software met set educational standards, including the criteria implied by the National Curriculum. Alternatively, spectacularly good packages could be singled out for special recognition in the same way that books, music and films receive awards. Running such a scheme need not be especially costly. A rating system could be run by a small independent body or by one of the government's existing independent agencies. A powerful way to ensure the assessment system is accurate, impartial and up to date would be to distribute software reviews via an educational Web site on the

Internet. Teachers, parents and indeed children could then not only read reviews of a particular package, but also vote on the extent to which they find it valuable and interesting. There are already examples of such software reviews on the Internet; the US Children's Software Revue is one (Exhibit 40).

Exhibit 40 USING NETWORKS TO DISTRIBUTE REVIEWS OF SOFTWARE



The concept of an educational Web site could be extended to include a 'marketplace' for software. Many teachers already adapt standard packages or write their own programs, but often in isolation. The Web site could include a section of software which would be freely available for immediate download. It could also include trial versions of commercial software and a help section where teachers and others seek advice and answer one another's questions. One attraction of this concept is that much of the content – the reviews, the advice and some of the courseware – would be provided by the users themselves. Running the site would be in many respects an editorial/technical function, and could be performed by a small number of full-time people.

Another attraction of an educational network is that the nature of software itself is changing. Software – by which we mean anything that transforms a piece of hardware and electronics into a meaningful application – no longer comes just in the form of a program on a disk, but can be a series of interlinked Web pages that reside on a network or the Internet. We have already discussed some examples of the World Wide Web being used to teach elements of geography and mathematics. Developing this type of interactive course work, which can be rich in graphical content, no longer requires complex programming knowledge, but can be done using straightforward 'authoring tools' developed recently.

Much of the software will still have to be developed commercially, however. Here, the government's role is to encourage information about packages' educational value, and, possibly, to orchestrate 'call-off' contracts at a discount for the most popular software, which could be extended to allow parents to purchase discounted software via their local school. SCET provides a good model for what might be achieved within the public sector. It has reduced its dependence upon grant income by developing software and services which have been sold to schools on a commercial basis, but at moderate prices.

Tackling network costs

Initiatives are already under way to encourage special arrangements to be made for schools. In the US, the Federal State Joint Board recently recommended that schools and libraries should be included within the obligation on telecommunications companies to support universal service. In particular, it recommended that all eligible schools and libraries should receive discounts of 20–90 percent on all telecommunications services, Internet access and internal connections, subject to an annual cap of $2.25 billion. It proposed that the discount levels vary according to whether a school or library is economically advantaged or located in a high-cost area.

In the UK, cable companies have recently announced special arrangements for schools allowing access to the Internet at flat rates using an ISDN or equivalent link of 64 kbps. This will cost £600 a year. The cable companies have also announced, as another option, a tiered, fixed-price tariff, which ranges from £100 a year for schools of up to 250 pupils to £500 a year for schools with over 500 pupils. There are no time-of-day restrictions on this service, so pupils will have access to the Internet not just during class but in after-school clubs and during school holidays. Teachers will also benefit by being able to use the Internet out of hours to support their classroom work at no extra cost.

The cable industry estimates that about 17,000 schools will have the option of these schemes by the turn of the century, once the building out in current cable franchise areas is complete. OFTEL has welcomed the arrangements and confirmed that it will permit other telecommunications operators, including BT, to offer similar lower and non-usage based charges, if they choose.

As well as the cable companies, other corporations too have the means to provide access to the Internet. These include not just BT but also the many Internet and online service providers. In the US, high-speed Internet access is being offered via satellite by Hughes Corporation, permitting access speed of up to 400 kbps at relatively low cost. This could be provided via satellite in the UK. The US Federal Communications Commission FCC has also just made available a band of public radio spectrum, free of charge, that could provide Internet access at low cost via wireless to schools and other public bodies.

Within schools themselves, there are many ways in which the costs of laying an internal network can be minimised. During the US 'Net Day' initiative, for example, volunteers from the community and local businesses helped to wire up their local schools. At one school, five classrooms and the library were joined to the Internet in just one day using hundreds of volunteers, materials donated by industry sponsors and tools borrowed from local businesses. To be effective, this kind of initiative would require close cooperation from local businesses, including cable companies, telecommunications operators, systems integrators, data network companies and others. Assuming that it applied at a national level, it would also need central sponsorship and coordination (Exhibit 41).

Exhibit 41 NETDAY EXPERIENCE OF FRANKLIN JUNIOR HIGH SCHOOL

Date: March 9, 1996
Goal: To install wiring to connect 5 classrooms and the library to the internet
Resources:
- Hundreds of volunteers
- Wiring materials donated by industry sponsors
- Tools borrowed from local businesses

Source: http://members.aol.com/FranklinJr

Costs can also be cut by harnessing community involvement in support and maintenance. Again in the US, a successful pilot exercise at Issaquah involved pupils helping to install, maintain and run computer equipment and networks. Pupils are also involved in training other students, parents and teachers, and take turns to man the computer help-desk (Exhibits 42 and 43).

Exhibit 42 DRAWING ON STUDENT EXPERTISE: ISSAQUAH* TECHNOLOGY INFORMATION PROJECT (TIP)

With limited teacher guidance, students enrolled in TIP carry out a variety of computing-related activities designed to give them practical knowledge and experience – e.g.,

- Installing and maintaining computer equipment and networks
- Programming and using application software
- Training fellow students, parents and teachers
- Manning computer help desk

TIP achievements

- Networking of 24 school district sites connecting 10,500 students and 1,000 teachers
- Creation of Issaquah community web server
- Reduction in computer system costs of almost 80% – as almost entire system has been built and managed by 12-17 year old students

* School district located in Washington State, USA
** Extract from course description, 21/7/94
Source: http://www.microsoft.com/K-12/resources/truestory/siaissaq.html; http://alphasvr.liberty.issaquah.wednet.edu/tip contract.htm; "Plugging in to their future," The News Tribune, 12/2/96; "Issaquah Miracle", Forbes ASAP, 7/6/96

Exhibit 43 THE ISSAQUAH EXPERIENCE

"(My) job has shifted from one of computer programming lecturer to coach … it's a completely non-traditional way to teach. Kids are working as apprentices to older kids. Every computer here is equipped with a teenager"
Don Robertson (teacher heading TIP programme)

"A student (can) graduate and say "I managed 30 Windows NT servers supporting 3,000 computers" … You graduate with real skills that relate to the business world and they're measurable"
Michael Bookey (parent of Issaquah student and computer network consultant)

"(In TIP the way I was taught was) that someone gave you a project and would say: "This is what I want you to come out with. Go do it". If I had a problem I had to call people or read books…I learned how to be a student, how to deal with people from the teacher. All the technical knowledge was taught by other students co-operatively"
Lee Dumas (former "Principal's nightmare" who became TIP computer guru)

Source: http://www.microsoft.com/K-12/resources/truestory/siaissaq.html; "Plugging into their future", The News Tribune 12/12/96; "Issaquah Miracle" Forbes ASAP, 7/6/93

Not only did the project immeasurably increase the IT skills of those involved, but it succeeded in connecting 24 school district sites, creating a Web server with content relevant to the Issaquah community and reducing computer system costs by almost 80 percent. In terms of the value participants derived from the exercise, their comments, above, speak for themselves.

All these options deal with the networks' physical infrastructure. In addition, in the sections on software and teacher training, we have outlined ideas for developing educational resources on the Internet that could increase the flow of software and educational content to children, as well as provide support and training for teachers. All could be incorporated under the umbrella of an educational resources Web site. Such a site need not be especially complex technically, and could be hosted on a limited number of Web servers. Although much of the content would be provided by those who use the network – software reviews or teaching ideas e-mailed to the site by teachers, for instance – a small team providing full-time editorial management would be needed.

Upgrading the hardware

The main issues to be addressed here are the need to upgrade outdated hardware to ensure that all schoolchildren, especially those who do not have a computer at home, have access to a machine, and to encourage a more uniform spread of facilities in schools.

This report does not seek to make any recommendation for a particular level of provision in schools. Such decisions can only be taken in relation to the overall budget available for education, which goes beyond the scope of this report. However, purely for illustrative purposes, and to understand the broad differences between different scenarios, we have analysed the costs of various indicative configurations of school infrastructure and external network connections. These are:

- ***A computer 'laboratory' model,*** which assumes that each primary school has enough computers in a single room for one class (an average of 27 machines), and that each secondary school has three such rooms (each with an average of 22 machines.) This is similar to today's level of provision for secondary schools, but is twice the average level of provision in primary schools today – the implication being that resources for primary and secondary schools would be brought more closely into line.

- ***A 'demi-classroom' model,*** in which computers are distributed throughout the school with five machines in every other classroom (for both primary and secondary schools).

- ***A 'classroom' model,*** again with computers distributed throughout the school but with five machines in every classroom.

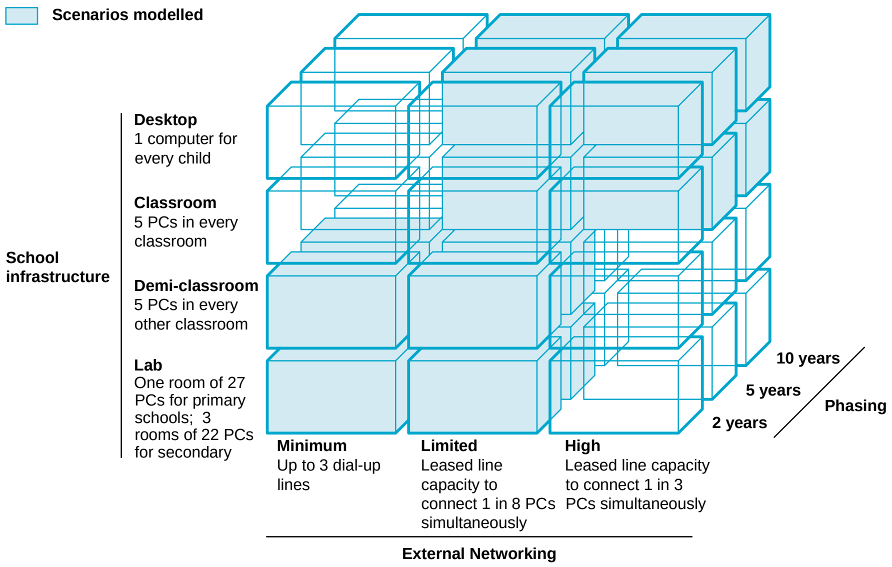
- ***A 'desktop' model*** with one computer per child.

In addition, we have looked at options for external network connections, varying from:

- ***A 'minimum' connection*** with up to three ordinary dial-up analogue lines to each school (the exact number depending on the number of machines).
- ***A 'limited' connection*** with a digital ISDN or leased line connection with enough capacity to connect one in eight computers simultaneously.
- ***A 'high-bandwidth'*** connection with enough ISDN or leased line capacity to connect one in three computers simultaneously.

The figures used for network connections are based on current commercial rates and do not reflect cable companies' recent arrangements or any discount that other telecommunications operators might offer. The cable companies' offer is most relevant to the 'minimum' and 'limited' scenarios, both of which represent a substantial step forwards from the minimal amount of external networking seen today. In each case, we have assumed that old equipment is replaced at a rate of 20 percent a year – equivalent, when applied over a period, to replacing computers every five years – and that the target level of machines is reached over a period of two, five or 10 years (Exhibit 44).

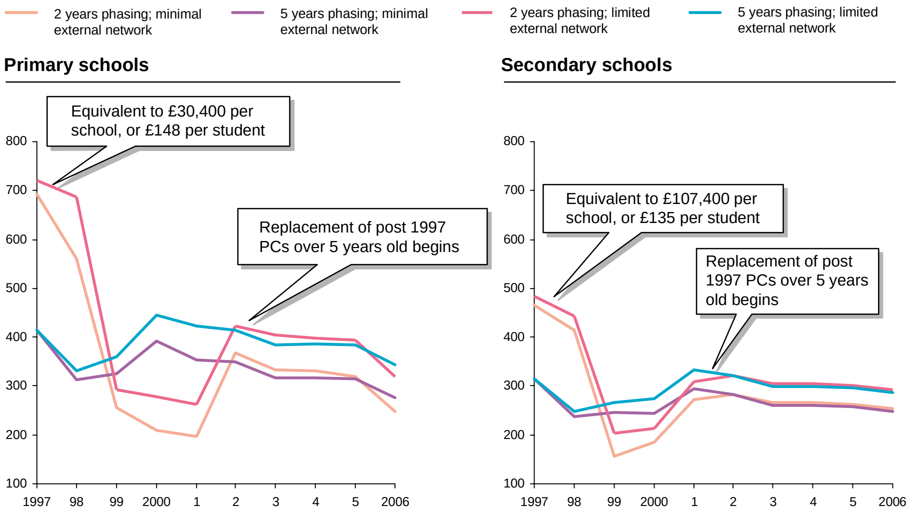
Exhibit 44 HOW THE VARIOUS SCENARIOS HAVE BEEN CONSTRUCTED



The results of this analysis are summarised in the Appendix. As an illustration of one of the scenarios, under the 'laboratory' model, the total cost for primary and secondary schools combined ranges from £730 million to £1,200 million a year in the first year depending on whether replacement machines are phased in over five or two years. These amounts fall to a steady state expenditure of between £520 million and £610 million by 2006 (at today's prices). While these amounts appear large, the steady state expenditure is not wholly inconsistent with the total expenditure of over £190 million actually incurred in 1993–94, which had been growing at a rate of 50–75 percent a year (assuming that such growth rates continue for the next few years within a decentralised framework of expenditure) (Exhibit 45).

Exhibit 45 **TOTAL UK COSTS: LAB MODEL***

£ million



* Further details contained in Appendix

Source: School cost model

This, and the other scenarios examined in the Appendix illustrate total expenditures and, with the possible exception of the costliest proposals, might be administered within today's decentralised financial system. To achieve a more modern and uniform infrastructure within schools, however, some central measures may be needed. To help avoid the wide variations in levels of provision between schools, government could set minimum targets, including standards for the maximum age at which a machine is deemed to be educationally useful. Such measures would encourage schools to upgrade where necessary, but in the spirit of a decentralised framework of expenditure. 'Cyberatings' could be published to highlight different levels of provision between schools.

Furthermore, existing hardware could be used more effectively. In the US, Boston's Computer Museum and the MIT Media Laboratory have organised a series of community centres providing computer access for children and adults outside school hours, with an emphasis on self-paced learning. At one of them, the Boston Computer Clubhouse, participants have been involved in exercises ranging from developing interactive reports for school projects to designing computer animations and learning programming techniques. Facilities in schools and elsewhere could be used in a similar way outside school hours in the UK (Exhibit 46).

Exhibit 46 OPENING THE INFRASTRUCTURE TO THE COMMUNITY - THE BOSTON COMPUTER CLUBHOUSE*

Description

- "Next generation" community centre providing free computer access
- Focus on developing children's "technological fluency" – i.e. ability to express themselves using technology
- Mentors (both young and old) act as role models for newer participants, and encourage involvement in technology-related projects
- Emphasis on self-paced exploratory learning

Example Projects

- Building computer interfaces to control motorised devices, such as robot arms and toy cars
- Designing and programming computer games
- Developing an interactive multimedia report for a school project
- Creating a mock laser light show by computerised control of motorised cars with mirrors and lights attached
- Designing computer animations

* Organised by the Computer Museum and MIT Media Laboratory
Source: "Computer Clubhouses in the inner city", The American Prospect, July-August 1996; http://www.cooknet.org/non-profits/clubhouse.html

ACHIEVING THE RIGHT BALANCE AND FOCUS

A number of factors are relevant in deciding the mix and focus of these opportunities. These are: how IT spending is balanced between primary and secondary education; how far resources should be directed towards giving teachers equipment and training; and the relative weighting of local, central and private financing. In this section, we set out some observations.

While primary and secondary schools alike have benefited from earlier IT policies, secondary schools have received about twice the number of computers per child as primary schools. Most primary schools also have older machines and usually little or no internal network. Yet it could be argued that basic literacy and numeracy skills – areas in which IT has an important role – should be improved at the primary stage, before children fall behind. In addition, much of the graphical and visual software that is particularly appropriate for primary-age children requires modern multimedia computers, with fast processors capable of being networked or connected to a CD-ROM drive. We therefore suggest this factor be looked at as part of an integrated strategy and in determining any minimum levels of provision.

In terms of the balance between providing for teachers and pupils, we have already commented on the need for improved support and training for teachers, including giving them access to machines, ideally of their own. Since without teacher support, any other investment in computers in schools is likely to be wasted, resources for teachers have to be a high priority. Such an initiative would be particularly powerful if combined with training and a network of resources for teachers, accessible via the Internet.

In terms of the money to pay for this, the main challenge is to stimulate and channel the local momentum that already exists rather than to undertake central initiatives aimed at 'hardware push'. Clearly though, the amount schools need to spend to achieve adequate provision has to be important in determining the total resources made available for education – otherwise IT could be crowded out as an avoidable, albeit desirable, item. Conversely, there may be instances in which IT, by increasing productivity, has the potential to reduce costs; this is beyond the scope of this report, however. There may also be some need for central financing of specific initiatives – those concerning software, computers for teachers or the development of a resources network, for example.

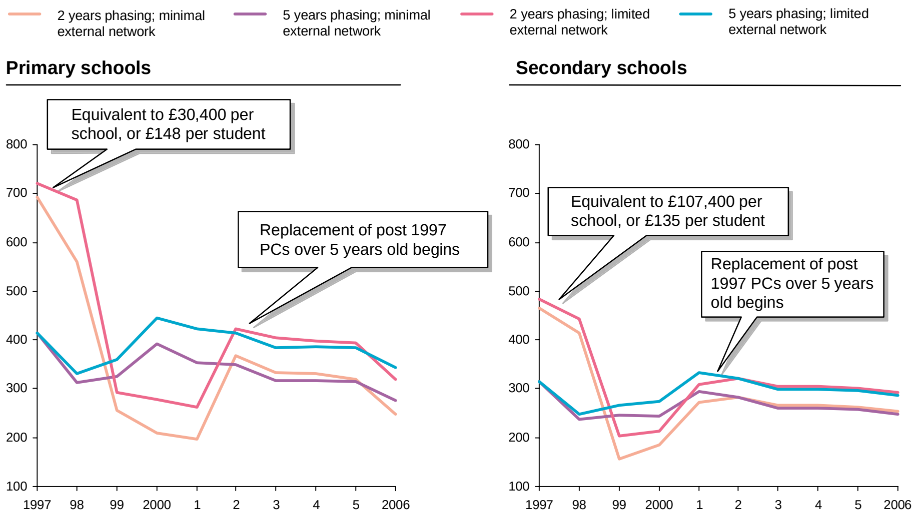
Finally, we would reiterate the importance of a cohesive strategy for the use of IT in education, that both enhances the way in which computers are used in schools, and which extends these opportunities to the home and the community. This is particularly true, now that computers can be used not just as data processing machines, but as a powerful platform for communications and sharing information. Many of the building block initiatives suggested in this report are by themselves relatively straightforward and minor in terms of their cost implications. But, taken together, we believe that these, and initiatives that others will suggest, could form the basis of a new integrated approach that could herald the beginning of a new era of IT in education.

APPENDIX: ANALYSIS OF INFRASTRUCTURE SCENARIOS

Under the 'laboratory' model, the total cost for primary and secondary schools combined ranges from £730 million to £1,200 million a year in the first year depending on whether replacement machines are phased in over five or two years. These amounts fall to a steady state expenditure of between £520 million and £610 million by 2006 (at today's prices) (Exhibit 47).

Exhibit 47 TOTAL UK COSTS: LAB MODEL*

£ million



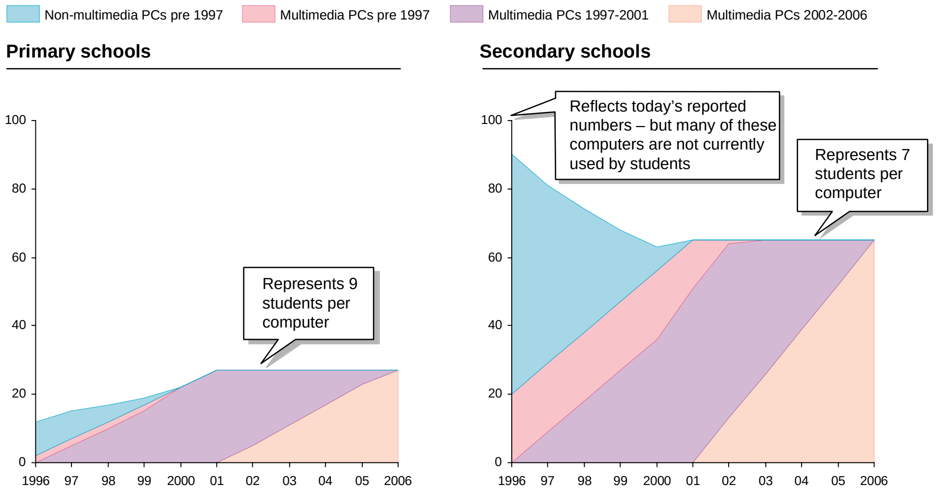
* Further details contained in Appendix
Source: School cost model

In terms of the number of computers that would then be installed, the laboratory model does not represent an increase from today's level. It simply amounts to upgrading today's stock of machines so that they are capable of running modern, interactive applications. As the chart below illustrates, the effect would be that by 2001, all machines would be at this level (Exhibit 48).

In the 'demi-class' scenario the total costs in the first year are similar, from £770 million to £1,250 million, depending on the precise phasing and capacity of external network connections. These costs would fall to between £450 million and £560 million by 2006 (Exhibit 49).

Exhibit 48 INSTALLED BASE: LAB MODEL (5-YEAR PHASING)

Number of computers per medium-sized school*

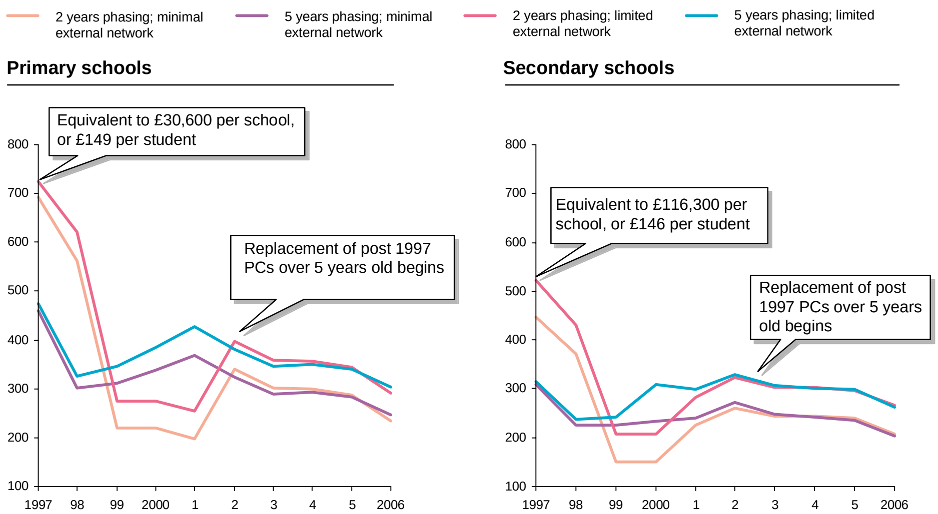


* There are 239/448 students on average in a medium sized primary/secondary school

Source: School cost model

Exhibit 49 TOTAL UK COSTS: DEMI-CLASSROOM MODEL*

£ million

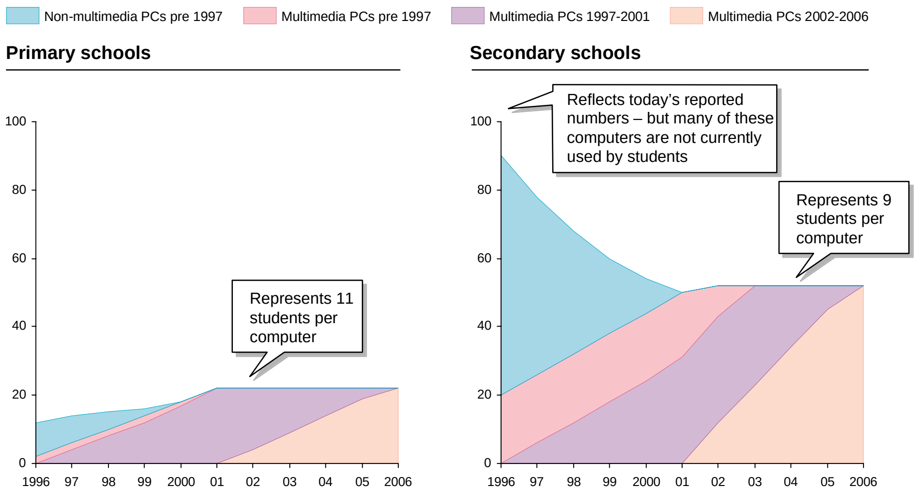


* Further details contained in Appendix

Source: School cost model

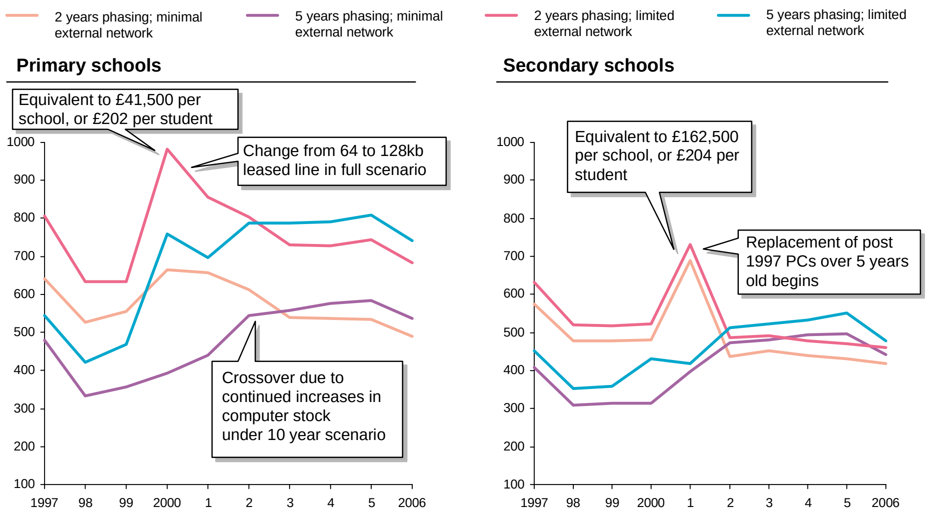
The main difference between this model and the laboratory model is that the number of machines in secondary schools would be slightly lower, and that the financial savings would be offset by the higher cost of maintaining the computers when they are scattered throughout a school. In broad terms, both the laboratory model and demi-class model would represent about 3.3 percent of today's education budget for secondary schools, and 4.2 percent for primary schools (Exhibit 50).

Exhibit 50 INSTALLED BASE: DEMI-CLASSROOM MODEL (5-YEAR PHASING)
Number of computers per medium-sized school*



* There are 239/448 students on average in a medium sized primary/secondary school
Source: School cost model

Exhibit 51 TOTAL UK COSTS: CLASSROOM MODEL*
£m



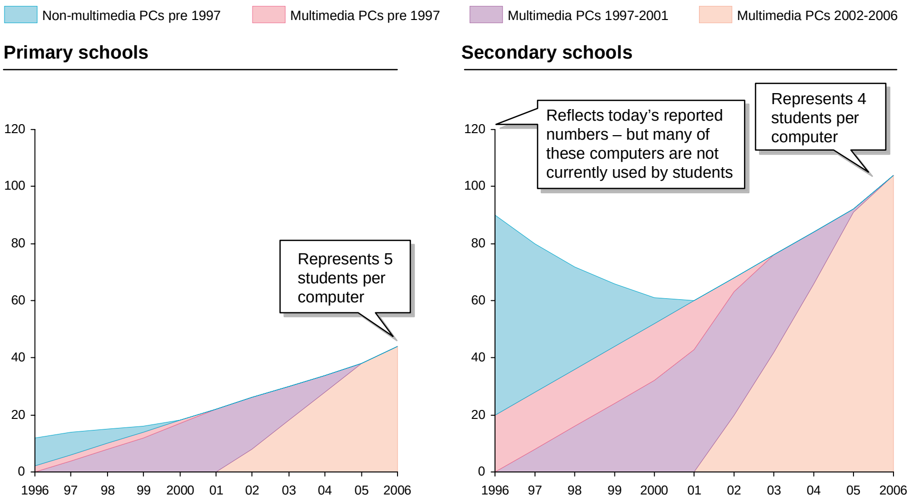
* Further details contained in Appendix
Source: School cost model

Under the 'classroom' model, which would put five computers in all classrooms, provision would be significantly higher (Exhibit 51).

Here, costs would range from £880 million to £1,470 million in the first year and fall to a steady state expenditure of between £990 million and £1,140 million by 2006.

Under this scenario the numbers of computers in schools would rise well above today's levels (Exhibit 52).

Exhibit 52 INSTALLED BASE: CLASSROOM MODEL (10-YEAR PHASING)
Number of computers per medium-sized school*

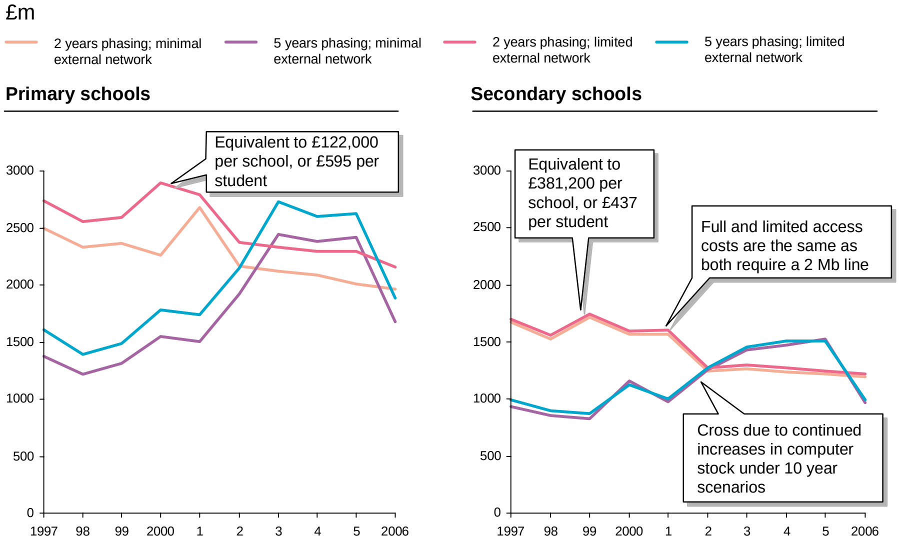


* There are 239/448 students on average in a medium sized primary/secondary school
Source: School cost model

In each primary school, there would be getting on for 50 computers by 2006, four or five times today's level. In secondary schools, the number (based on today's reported figures) would decline between 1997 and 2000, although these figures are somewhat artificial because many older computers included in the count are not actually used. From the beginning of the next century and beyond, the number of useful computers would rise substantially to reach over 100 machines in each secondary school by 2006. Again, by the turn of the century the effect would be an almost completely modernised hardware base.

Finally, under the 'desktop model', expenditure would rise to levels that are probably unrealistic unless specific funds are found for the purpose. Here, the costs range from £2,300 million to £4,400 million in the first year, falling to a total cost of between £2,600 million and £3,300 million in 2006 (Exhibit 53).

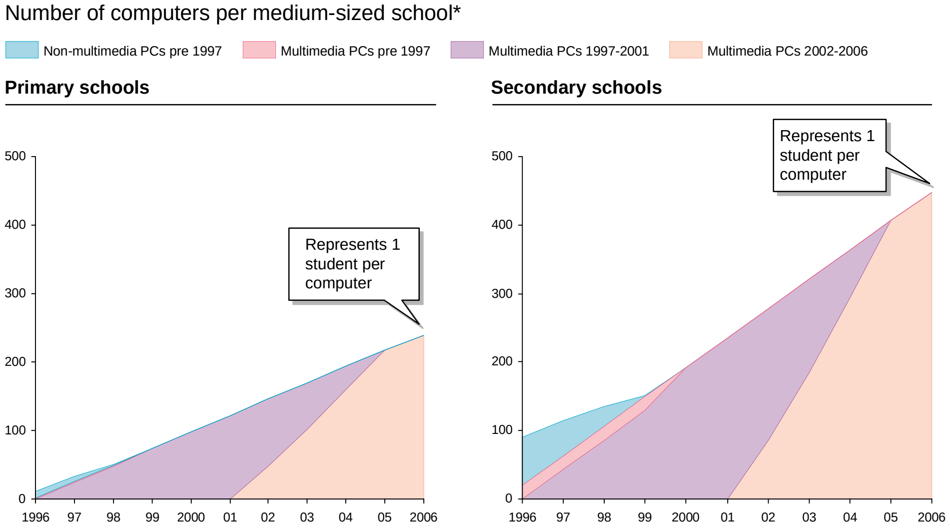
Exhibit 53 **TOTAL UK COSTS: DESKTOP MODEL***



* Further details contained in Appendix
Source: School cost model

The effect would be that by 2001, each primary school would have about 150 machines, rising to 240 by 2006. In secondary schools the figure would be 250 machines in 2001 rising to well over 400 by 2006 (Exhibit 54).

Exhibit 54 **INSTALLED BASE: DESKTOP MODEL (10-YEAR PHASING)**



* There are 239/448 students on average in a medium sized primary/secondary school
Source: School cost model