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ABSTRACT

This report examines decisions regarding investments in K-12 technology. The first section presents an overview of technology in K-12 public schools, including a sampling of how technology is being used to further education goals for teachers, students, and administrators. The second section establishes a set of figures that indicate the current installed based, i.e., the level of computer hardware that exists in U.S. public schools. The third section discusses technology, education, and demographic trends affecting today's decisions. The fourth section looks at technology investment approaches, including advantages, disadvantages, and costs of enhanced desktop, laptop, thin client, education service provider, and state e-learning framework scenarios. The fifth section discusses the following additional factors to consider: state approaches to funding education technology; and the total cost of ownership, including professional development, wiring and networking costs, technical support, security, software and digital content, equitable access to technology, and building infrastructure. The conclusion lists decision points and policy questions for policymakers. Appendices include a list of key terms, a list of sources reviewed to estimate the current installed base of technology equipment, data from seven reports on the current installed base, and a chart of state approaches to funding education technology. (Contains 57 references.) (MES)

Investing in K-12 Technology Equipment: Strategies for State Policymakers

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Executive Summary

Education decisionmakers today are grappling with difficult and significant decisions regarding investments in K-12 technology. Once a decision to invest in technology is made, policymakers need useful, reliable information regarding the options at their disposal. The Bill and Melinda Gates Foundation asked the Education Commission of the States (ECS), a nonprofit, interstate compact dedicated to providing state policymakers and education leaders with information on education issues, to prepare a report in response to that need. *Investing In K-12 Technology Equipment: Six Strategies for Policymakers* is that report.

ECS assembled a team of education technology and finance experts to look at the current installed base of technology in the nation's public schools and identify strategies for future investments. The intent of this report is to focus on investment strategies for technology equipment, notwithstanding the fact that equipment is only one portion of the investment package. Therefore, it is important to note that the findings and figures presented here, except for those addressed in Finding 5, represent the investment for equipment only, and do not take into consideration other key costs, such as professional development, technical support and network infrastructure. The total cost of technology is a very important consideration that is discussed briefly at the end of this report, and at length in a number of other reports.

Technology's costs are substantial and ongoing. If organizations are not prepared to commit annual funds for updating, maintaining and supporting technology use in the schools, monies for technology equipment may be better spent elsewhere. School districts would not think of buying buses without budgeting annually for such costs as maintenance, fuel and mechanics, along with periodic fleet replacement. Technology requires no less.

Various state approaches to funding education technology are addressed in Section V. Aside from funding considerations, state leaders may also wish to review statutes and regulations to ensure that barriers to leasing options for schools and districts are removed. Leasing equipment allows schools to install modern equipment with lower up-front costs and may result in cost savings. Equipment leasing is applicable to any of the options discussed in this report and represents an alternative worth investigating for any school or district committed to the educational use of technology.

Because each school and district is unique with respect to the quality and functionality of its existing equipment, cost estimates for upgrading and replacing the installed base assume that schools are starting at ground zero; i.e., no equipment base is assumed. In addition, the projections reflect a single, up-front investment, whereas in reality most schools will phase in purchases over a period of three to five years. Further, the investment scenarios are discrete and do not mix laptops, for example, with desktops, though combinations of types of technology equipment are to be expected. When using this report, readers may wish to use inventory data from their own jurisdiction to determine what portion requires replacing or updating, then use the estimates from the school-building level to build any combination of equipment options.

Five key findings emerge from this report.

- ***Finding 1***. At least 2.8 million of the estimated 7.1 million computers currently installed in America's schools can be considered aging or limited in use. These computers cannot use most Internet resources or recent software. To upgrade the installed base while continuing to lower the ratio of students to computers will require a substantial investment of capital over the coming years.

Current Installed Base

Type of Equipment	Existing	Number That Need To Be Replaced
Apple Computers		
- Macintosh*	2,591,500	-
- IIe's	745,500	745,500
IBM/IBM Compatibles		
- Pentium	1,704,000	-
- 486 or 386	1,278,000	1,278,000
- 286	426,000	426,000
- Other	355,000	355,000

*No distinctions are made in available data sources between older and newer Macintosh computers. The authors assumed that these are "modern" devices.

- ***Finding 2.*** The minimum estimated cost for updating the nation's education technology equipment is $1.5 billion to 7.6 billion. The simplest strategy is to invest in more of the same; i.e., replace aging desktop computers with updated desktop computers. Such an approach requires a national investment in the range of $1.5 billion to $7.6 billion. The lower figure is based on using scaled-down desktops that emphasize network connectivity rather than stand-alone functionality (referred to as iComputers). The higher figure represents replacing aging equipment with high-end desktop computers.

Replace Aging Desktops with New Desktops

Type of Replacement	Cost to Replace	Cost per Pupil to Replace
iComputers	$1,576,129,000	$34
Low-End	$2,939,116,000	$64
Middle-Range	$4,405,869,500	$96
High-End	$7,692,743,500	$167

The key differences between low- and high-end computers center on speed and quality. Some argue that low-end computers will become obsolete more quickly due to a growing mismatch of hardware capabilities to software and networking demands. The obsolescence cycle, or life cycle, of the equipment is therefore an important consideration. [See Comparison of Alternatives Across Multiple Variables following Finding 5.]

- ***Finding 3.*** To update and upgrade technology equipment simultaneously will require an investment in the range of $22.5 billion to $36 billion. One alternative to the Replacement scenario is to provide a more robust version of desktop computing. This approach, termed Enhanced Desktop Set-Up, involves building a modern version of today's installed base of desktop computers, with lower student-to-computer ratios, computers for faculty and modern media centers. [See Methodology under Section IV on for explanation of differences in pricing per school level.]

Enhanced Desktop Set-Up

	Cost per Elementary	Cost per Elementary Student	Cost per Middle School	Cost per Middle School Student	Cost per High School	Cost per High School Student
Low Cost	$202,602	$450	$394,397	$563	$515,746	$688
High Cost	$280,323	$623	$557,886	$797	$745,973	$995

- ***Finding 4.*** New technology equipment alternatives are feasible for schools as a result of advances in technology and telecommunications. Whereas the desktop configuration is currently the most prevalent in schools, laptops, thin clients and even hand-held computing devices are found in more and more classrooms. (Due to the lack of educational software for hand-held devices, this report does not include them among the options for equipment investment. Over the next few years, however, this is likely to change.) The chart below compares the per-pupil cost of desktops, laptops and thin client devices.

Comparison of Equipment Investment Alternatives

	Enhanced Desktop Scenario	Laptop Scenario	Thin Client Scenario
Per-Pupil Costs			
Elementary Low Cost	$450	$1,093	$418
Elementary High Cost	$623	$1,192	$860
Middle School Low Cost	$563	$2,458	$427
Middle School High Cost	$797	$2,486	$866
High School Low Cost	$688	$2,481	$647
High School High Cost	$995	$2,520	$890

Equipment costs are only one dimension of the investment decision; capability, life cycle, accessibility and intended use are additional considerations. For example, although purchasing laptop computers for every student is a relatively costly option, some districts think the investment is warranted.

- ***Finding 5.*** Beyond equipment, education agencies are investigating viable ways to use Internet technologies to meet education goals. The obsolescence cycle for computers is currently three to five years. To leverage the investment within this window of time requires that schools be ready to use these tools in ways that advance the mission of the schools. This means affordable access to software, online tools and knowledge bases. In addition to the equipment investment options outlined previously, states and districts may choose to invest in options with the potential to enhance productivity or connect state standards with tools for teaching and learning. Two approaches examined in this report are: (1) using an outside Education Service Provider to host and provide software applications, and (2) establishing a State e-Learning Framework that connects standards with curriculum, content and information systems. The table below compares the options in terms of life cycle, equitable access and costs, using a scale of Low – Medium – High, with Low being least desirable and High being most desirable.

Comparison of Alternatives Across Multiple Variables

	Life Cycle	Equitable Access	Costs
Desktop	Medium	Medium	Medium
Laptop	Low	High.	High
Thin Client	High	Medium	Low-Medium

Education Service Provider	High	Medium	Variable†
State e-Learning Framework	High	Variableº	Low

†The cost for bandwidth could be high, depending on existing infrastructure
º Participating schools provide access for all teachers and students, but home access will vary

Wise decisionmakers will adopt a proactive stance and consider the full range of options before deciding on a course for the future. This report provides readers with a sense of the current status of K-12 technology equipment, the trends likely to affect the near future and several investment options currently available to state and district decisionmakers.

Scenario Terms (see Appendix A for a more extensive list of key terms)
Education Service Provider – a company that hosts software applications remotely and lets schools use them via the Internet or a private network for a fee Enhanced Desktop Set-Up – similar to what currently exists in many schools, but with a lower student-to-computer ratio and more supporting technology, including faculty computers and a modern media center [see Target Technology, Methodology] iComputers – scaled-down desktops that emphasize network connectivity rather than stand-alone functionality State e-Learning Framework – a program designed to facilitate standards-based teaching and learning using Web-based tools, resources and services (after the Mass. VES model) Thin Client – a network-based approach to information processing, using a hardware device that transmits images to its screen from the server and permits input and output. These devices rely on network servers to run program applications and store data

Section I. Overview of Technology in K-12 Public Schools

Background

Ongoing capital replacement costs for technology are typically overlooked or underestimated. As is the case with school facilities in general, the pattern of deferred maintenance and replacement may temporarily ease problems caused by scarce resources, but such practice threatens to undermine the technology investment over the long term. Deferring decisions about next-generation technology investments may potentially drive up overall costs, and frustrate efforts to use technology effectively in America's classrooms.

After several decades of exploring technology uses in schools, the presence of technology in the classroom is no longer a question of "Why use it?" but "How best to use it?" Educational uses of technology are likely to expand, too, as Web-based content and applications multiply. In fact, several indicators point to the need to give careful consideration to capital replacement strategies for K-12 technology.

First, the public strongly supports technology in schools. The *New York Times* recently reported that 80% of Americans want the federal government to support computer literacy programs in high school to minimize the "digital divide." In addition, because nearly 70% of workers use a computer every day, parents want their children to be prepared to participate in a technology-driven economy and society. Employers in business and industry expect no less.

Second, substantial sums already have been invested in education technology. It would be foolish to allow this capital investment to languish. As the installed base of K-12 computing technology ages into obsolescence, technological progress marches on. Schools have learned the hard lesson that deferred maintenance of buildings results in more costly repairs and upgrades. The same holds true for the technology base.

Third, and most important, after several decades of experimentation, educators are beginning to understand how to use technology as a tool for meeting education goals. A growing base of research elucidates the essential conditions necessary for technology use to be effective.[1] Researchers and practitioners are sharing and learning best practices of successful educators using technology. Furthermore, technology developers are turning their attention and venture capital to the education market, a development that bodes well for the creation of tools needed by educators and students.[2] For too long, most education technology applications focused only on the student. New technology applications provide educators with tools for individualizing lessons, communicating and collaborating, tracking student progress and getting just-in-time professional development. In short, technology is playing an important role in teaching and learning.

Elected state officials and education agencies need to adopt a comprehensive, forward-thinking approach to capital replacement of K-12 education technology. More specifically, policymakers must recognize that the capital costs of technology are a recurring expense. In the past, one-time allocations for educational technology were appropriate; today, educating students for literacy in a digital society demands a permanent line for technology in state education budgets.

The pace of adoption is picking up as technology becomes ubiquitous in K-12 education and competition increases for students and teachers. Students and their parents will soon expect schools to keep pace with technology or will seek out education providers that do. Students and parents of every socio-economic level will demand equitable technology access and quality, and may well sue the state, if necessary, to get it. Technology is becoming essential to a first-rate education. It has become a cost of doing business and should be treated as such.

The days of one-time funding infusions that fail to take into consideration the total cost of ownership are waning. Technology underfunding is still common, though. Too often, technology plans are funded at only 25%-50%, forcing schools to ignore or delay the maintenance and upgrading features of the plans. In some districts, schools compete with each other for their piece of a funding pie that is far too small to go around.

Because the pace of technological change is so rapid, decisionmakers need to look ahead of the curve to anticipate new developments and evaluate the potential of new tools for improving education. Piecemeal funding, patchwork initiatives and stopgap measures will not make the grade in today's competitive educational climate.

It is time for policymakers to re-examine the investment in education technology with three objectives in mind. First, what do we hope to accomplish through technology use in schools? Second, what options best support those goals? Third, what are the costs and benefits associated with the various options? The primary purpose of this report is to shed some light on the last two questions so that decisionmakers may arrive at the table armed with solid information about the relative costs and benefits of various capital replacement scenarios. Before going further, though, here is a brief examination of ways that technology can support K-12 education.

How Can Technology Help?

Policymakers understandably need good reasons to appropriate millions of dollars toward investing in education technology. A growing body of research supports the notion that technology tools can enhance teaching and learning in meaningful ways. Here, briefly, is a sampling of how technology is being used effectively to further education goals.

Technology is helping teachers:

- Tailor instruction toward individual student needs; e.g., advanced or remedial lesson assignments
- Facilitate a student-centered approach to learning in which students play more active roles
- Align standards with content, practices, curriculum, resources and testing via Web-based tools
- Use new tools for diagnostic testing and prescriptive tutoring
- Manage their classes and administrative load more efficiently
- Gain access to professional development opportunities; e.g., online courses, collaborations, email and video communications.

Technology is helping students, including those at-risk or with special needs:

- Acquire skills and experiences necessary to being productive members of 21st century society; e.g. information literacy
- Participate in mainstream classes and society, and overcome physical and learning limitations through assistive technologies
- Experience authentic learning and work on real-world projects; e.g., producing a newsletter or building a Web site using professional-quality software
- Acquire critical thinking, problem solving and team building skills
- Connect with experts, mentors, and peers from around the world
- Improve their test scores as a result of gaining a deeper understanding of underlying concepts; e.g., using simulations to understand math concepts
- Build portfolios of student work that portray their understanding and demonstrate progress in learning
- Gain access to computers and the Internet when it is not available in the home or community settings.

Technology is helping administrators:

- Show accountability for education goals; e.g., tracking student progress on meeting standards
- Use comparative data to learn about effective practices in schools or districts with similar demographic profiles
- Manage student information and other education and operation systems more efficiently
- Measure the effectiveness of various pedagogical methods and interventions
- Improve communications between parents, students and teachers
- Encourage and provide new avenues for parental involvement
- Be more productive and communicate more effectively
- Engage in professional development activities such as participating in online discussion groups with their peers
- Offer community members opportunities to access technology and acquire valuable workplace skills.

Section II. Where We Are: The Current Installed Base

The purpose of this section is to establish a set of figures that indicate the level of computer hardware that exists in U.S. public schools.[3] In order to do this, the authors carefully defined the technology scope to be considered, then conducted a comprehensive review of technology research. Following the research review, the authors established a set of estimates that reflect information from several reports and surveys.

For the purpose of this report, technology is defined solely in terms of computing hardware. This includes computers (processor, monitor, CD-ROM, and keyboard), networks (local and wide area networks) and Internet access connections (T1, 56Kb, ISDN, cable modem, etc.).[4] Peripheral hardware, such as servers, printers, scanners, LCD projectors and digital cameras, do have cost implications, but are not addressed in this report due to a lack of reported information. Additionally, there are other costs associated with replacing technology that include expanded professional development for teachers and effective software for instructional purposes; but, again, the purpose of this report is to estimate the amount of technology that exists in schools.[5] Therefore, while these other costs are addressed in Section V, they are not included in the estimates of the current installed base or the primary investment options discussed in Section IV.

No definitive report exists that fully addresses all the important aspects of technology. Numerous sources provide information on educational technology, but oftentimes the statistics and information reported are too specific or too general and conflict with other reports published around the same time. Additionally, several reports that were published in the early and mid-1990s have useful information, but are now outdated because technology changes quickly. Ultimately, seven sources were selected that provide essential information about the level of technology hardware in U.S. public schools: National Center for Education Statistics (two reports), Education Testing Service, The CEO Forum, Center for Research on Information Technology and Organizations (CRITO), Quality Education Data (QED) and *Education Week*. These reports are described briefly in Appendix B. Of the seven reports and surveys, three were used to develop the estimated numbers in this section – *Education Week*, CRITO and QED. Those estimated numbers are illustrated in Appendix B along with a short explanation of what source was used to derive the estimate.

As the following table describes, there are approximately 7.1 million computers in U.S. public schools. More than 4 million of those represent multimedia computers. Most of the remaining units – 2.8 million – can be considered aging or outdated.

Table 1: Estimate of Existing Computer Hardware in U.S. Public Schools, 1997-99

Category	Estimation	Explanation
	Estimates of Computers	
Total number of computers	7.1 million	Average of EW and QED number of computer estimate[6]
Number of multimedia computers[7]	4.3 million	Average of EW and QED number of multimedia computer estimate (see footnote)
Number of Apple IIe computers	745,000	Number of the 7.1 million computers that are Apple IIe (QED)
Number of Macintosh computers	2,591,500	Number of the 7.1 million computers that are Macintosh (QED)
IBM/IBM Subcategory List:[8]		Number of 7.1 million computers that are IBM/IBM compatible according to the processor type (CRITO)
Pentium processor	1,704,000	
486 or 386 processor	1,278,000	
286 or slower processor	426,000	
Other type of processor	284,000	
	Internet Connectivity	
10% of schools NONE	8,700	Number of 86,600 schools that have different types of Internet access connections (EW)
T1	38,200	
ISDN	5,500	
Cable modem	5,500	
56Kb or individual/network modem	27,300	
Other type of connection	1,500	

Section III. Where We Are Going: Trends Affecting Today's Decisions

Policymakers and educators charged with making decisions about technology capital replacement are challenged by an ever-changing array of circumstances and options. The backdrop is moving even as this report is being read. Decisionmakers can anticipate some of these changes and use information about key developments to inform their technology investment choices.

In this section, emerging technology, education and demographic trends are examined for their potential effects on policy regarding capital replacement of computer technology. These trends inform the scenarios proposed in Section IV, and are useful when considering the various options for ensuring a modern technology infrastructure for tomorrow's schools. The focus here is on the key trends that could potentially affect capital replacement of computer technology in K-12 schools.[9]

At a glance, the key trends are as follows:

- Computers are becoming more powerful, more mobile and faster.
- Software is moving from desktops to networked and Web-based servers.
- Web-based applications make learning possible anywhere, anytime.
- Support for education technology is strong and growing.
- Expectations for student academic achievement are rising.
- Schools face increasing competition for students, teachers and funds.
- The teacher workforce is entering a period of major turnover with shortages predicted within the decade.
- Education finance is due for an overhaul.
- Student enrollment is rising, particularly in the West.

Technology Trends

Schools, districts and state leaders are increasingly called upon to grapple with policies regarding the purchase and use of technology. Some of the issues decisionmakers face include: providing access to technology beyond the school day; providing laptops for checkout or assigned for student use; extracting the full value of technology while it is still valuable and up to date; leasing versus purchasing options; providing community access to technology; and sharing costs of technology. Driving these trends are public demand for and increasing accessibility of technology for teaching and learning.

- Smaller, cheaper, faster machines. For years, goals aimed at reducing student-to-computer ratios were based on desktop PCs or multimedia machines. Such "fat clients" may soon be replaced by less expensive portables, Web appliances, digital set-top boxes for TVs or handheld computers. Devices that sell for $500 or less represent viable alternatives for educational computing.

  Policy Implications: It will be feasible to issue a personal computing device to each student in the near future. Some districts and states are already testing this model. Technology dollars now can shift toward applications that support standards and educational goals. Student privacy and high-tech cheating are among the new concerns that educators will need to address, as well as revisiting out-dated technology plans.

- Wireless computing on the rise. Wiring and cables are costly items in school technology budgets and the layout is difficult to modify as needs change. Now wireless technologies present a significant alternative for schools interested in flexible and mobile computing. Like telephones and pagers, laptops and Internet connections are no longer tethered to the nearest wall. Rather than plugging in and locking down computers in fixed configurations, schools are choosing the convenience of wireless laptops, which allow computing power to follow the demand. Being "wired" is often associated with a bank of computers against a wall in the back of the classroom. Being "wireless" means the number of devices in a classroom may vary from time to time and day-to-day depending on learning activities.

  Policy Implications: As with other technologies, the prices for network connectivity units are falling even as the speeds increase. Wireless technologies may soon bring Internet access to remote areas not currently served by cable or high-speed lines. In addition, wireless devices may help overcome some of the obstacles to effective classroom use of computers.

- Software as a service. In the coming year "software applications will begin a mass migration from the desktop to network servers and online application service providers," according to a report on key trends shaping the digital economy[10] published by the Software and Information Industry Association. This evolution in software publishing is expected to "lower prices, improve products and greatly enhance access to sophisticated applications." In addition, software on network servers will reduce computer downtime and demand for onsite technical support.

  Policy Implications: Organizations that choose to lease software from online providers may require less technical support, freeing up resources for reallocation to support other learning and instructional activities. However, online application services require considerable bandwidth, something that many schools lack.

- Anytime, anywhere learning. Nearly 98% of U.S. schools are wired for Internet access, according to Quality Education Data, and, by the end of 2002, nearly 70 million U.S. households are expected to be online. K-12 students, parents, teachers and administrators represent about 45% of the population. As more schools provide school-to-home and school-to-community links via the Web, students, parents and teachers will be able to tap into resources and work on assignments anytime, anywhere.

  Policy Implications: Many schools and districts already have Web sites with extensive resources, whether through outside service providers or their own programs. Investing in Web-based applications is an alternative policymakers will need to consider. Another challenge to education leaders who do choose to take advantage of Web-based applications is how best to use the extended learning time.

- Support for education technology grows. Parents, businesses and politicians are generally supportive of education technology. Seven of 10 voters say it is important for schools to be equipped with computers and modern technology, according to a 1997 poll by Peter D. Hart Research Associates Inc. Investments in technology are increasing, as state and federal programs aim to provide universal Internet access for schools and integrate technology into instruction. At the same time, a growing contingent is speaking out against education technology, particularly for children in the early grades.

  Policy Implications: Technology backlash is not strong enough to prevent policymakers from making innovative and bold decisions concerning education technology. Inaction regarding an aging technology base may prove unwise. The challenge is to act with foresight and develop broad public-private sector cooperation to build an education system infused with powerful learning technologies.

Education Trends

The stakes are rising for educators and students on every front. Students can no longer earn a diploma simply by putting in seat time. Teachers are expected to deliver higher student test scores. At the same time, teachers are leaving the field in droves. The demands on schools are so varied and urgent that alternatives to the traditional public school model are proliferating. Finally, funding formulas and finance codes created decades ago are under scrutiny amid these changes. The business of education is changing rapidly and significantly.

- Focus on student achievement. Expectations of the U.S. education system have grown beyond merely giving students access to school and encouraging attendance. Today the focus is on academic achievement for all children. States have adopted standards and have implemented accountability systems to increase student achievement. Online assessments and digital portfolios are among the new tools for monitoring student achievement.

  Policy Implications: Emerging technologies hold promise for being able to help improve student achievement, with tools that include diagnostic testing and prescriptive tutoring, systems for tracking a wide range of student progress indicators and the ability to tailor instruction to individual student needs.[11] Policymakers will face decisions on which investments – including professional development for teachers and non-technology options – will yield the best results for student achievement.

- Education gets competitive. Competition among schools for students, educators and funds is increasing. Home schools, magnet schools, open-enrollment programs, charter schools, virtual schools, tax credits and vouchers point to the proliferation of school choice, which is driving competition for students and teachers. Districts are increasingly contracting with private providers for education services. Moreover, with education representing a significant component of the digital economy, venture capital is streaming to businesses offering content and Web-based services to education consumers. K-12 public education will be competing with sophisticated private providers for students and staff.

Policy Implications: At a time when school choice is increasingly popular, many parents will opt for schools that offer students, teachers and parents the best technology tools for learning and teaching. Rising expectations for student achievement are matched by expectations for high school graduates prepared to use technology in work environments. Public schools that fail to meet these expectations are likely to suffer.

- Turnover in teacher workforce. Retirement, burnout and career changes will lead to replacement of 75% of current U.S. teachers in 10 years, according to Education Testing Service.

  Policy Implications: The recruitment and training of more than one million new teachers by 2010 poses both a challenge and an opportunity for education. Colleges of education must gear up to give pre-service teachers the skills to succeed in 21st century education. Alternative certification of professionals experienced in non-educational fields may offer a temporary solution. "CyberCertification" of online instructors from out of state is another option. Policymakers will need to consider ways of recruiting the best and brightest to the field of education. Providing sophisticated technology support systems may aid in accomplishing this goal.

- Funding formulas and finance codes are being examined anew. Concerns about inequality and interest in incentives for better performance are causing state policymakers to defend and/or revamp longstanding education funding approaches. California, Vermont, New Jersey and Kentucky are among states that have been taken to court over education funding formulas that are seen as unfair or unconstitutional. Forty-one states, in fact, have faced court rulings over school funding, and the trend is likely to continue. After Kentucky's entire public school system was declared unconstitutional in 1989, the state initiated sweeping reforms focusing on school finance, governance and curriculum.

  Policy Implications: States may well be asked to help close the digital divide, to bring students with little or no access to computers and the Internet to parity with those who have abundant access at school and home. Further, in light of education technology changes, finance codes can be redefined to give districts and schools more flexibility. For example, technology purchases under $1,500 can be classified as non-capital expenditures. In addition, textbook, materials and assessment expenditures are likely to change as more content and assessment services are automated or outsourced and offered online. Opportunities for resource allocation are substantial, providing policies permit flexible use of funds at the district and school levels.

Demographic Trends

Policymakers need to consider the changing characteristics and size of the student population when planning for infrastructure investments. More students and more diversity are projected in the years to come.

- Tomorrow's school population is likely to be increasingly diverse. The U.S. Census Bureau projects the majority of America's school-age children will be members of a racial/ethnic minority by 2030, with nearly one in four of Hispanic origin.

  Policy Implications: District and school officials may be able to take advantage of technology to ameliorate language difficulties (through software in multiple languages, for example), as well as track programs and interventions that work best for various student populations. For example, one study found that ESL students fared best when they were grouped with other ESL students, not mainstreamed as some might expect.[12]

- Student enrollment rising in some regions. The school population is growing due to the Baby Boom echo and immigration. According to the U.S. Dept of Education's National Center on Education Statistics,[13] public elementary and secondary school enrollment was projected to reach 46.7 million in 1999 (up from 44.8 million in 1995), and to increase further in subsequent years. The West will experience the majority of this growth in the student population.

Policy Implications: The growth in student enrollment will place new demands on staff, space and school resources in the coming decade. Education agencies will need to consider population size when planning for education technology. Plans that call for lower student-to-computer ratios or computers for every student will be affected most.

As the trends discussed here indicate, education and policy leaders will be called upon to respond to, or preferably anticipate, a great deal of change in the education environment. In addition to the kinds of purchases explored in this report, more options and challenges are to come that require flexibility and nimbleness in decisionmaking.

Section IV. A Look at the Options: Technology Investment Approaches

Several of the many options available to today's decisionmakers are explored in this section of the report. To replace, without attempting to build on, the existing base of computers will require an investment of at least $34 per student (for iComputers), and up to $167 per pupil for high-end computers. Bringing the installed base toward an Enhanced Desktop Scenario – with a lower student-to-computer ratio and a full complement of supporting technology, including faculty computers and a modern media center – will require an investment in the range of $450 to $1,000 per student. These estimates are based on the one-time purchase of traditional desktop computers, assuming that no existing equipment will be retained.

Before investing in a new generation of desktops, decisionmakers would do well to examine the alternatives. One alternative employed in a growing number of schools is a Thin Client solution. With costs in the range of $400 to $900 per student, the up-front investment is about the same as for the Enhanced Desktop Scenario. However, Thin Clients may provide cost savings over the lifetime of the equipment, with an expected life span of 8-10 years, and significantly lower costs for ongoing maintenance and technical support.

Some districts and a few states are examining the option of providing a laptop computer for every student. At $1,100 to $2,500 per student, the Laptop Scenario is more costly than other alternatives, but proponents argue that student learning and productivity will be greater with around-the-clock access to computing. Note that schools will likely need to replace the laptops every two or three years due to wear and tear.

Comparison of Alternatives

	Enhanced Desktop Scenario	Laptop Scenario	Thin Client Scenario
Per Pupil Costs			
Elementary Low Cost†	$450	$1,093	$418
Elementary High Cost	$623	$1,192	$860
Middle School Low Cost	$563	$2,458	$427
Middle School High Cost	$797	$2,486	$866
High School Low Cost	$688	$2,481	$647
High School High Cost	$995	$2,520	$890

† Speed and quality of equipment are the variables that differentiate the Low Cost and High Cost estimates.

Two additional alternatives – the Education Service Provider and State e-Learning Framework scenarios – offer ways to *use the existing installed base* to maximum effect; i.e., to boost productivity and learning. These scenarios are unique in that they take advantage of Web-based delivery of software and services in order to minimize the burden on schools and educators to devise ways to use technology to enhance learning. These scenarios do not necessarily involve investing in new equipment; nevertheless, states and other education entities interested in these options may want to consider equipment purchases in order to modernize and reduce student-to-computer ratios. These scenarios are included in this report because they represent significant alternatives to the traditional use of technology in education. As for the State e-Learning Framework, it can be considered an overlay to and augmentation of programs at the local level.

With the high cost of software and the time-consuming nature of keeping programs up and running on each computer in the school, some schools are turning to Education Service Providers (EduSP) to host and maintain a full menu of software titles. The school reallocates funds for purchasing software and licenses toward leasing software through the EduSP, and gets more software applications per dollar in return. At the same time, the school outsources the technical support and staff time associated with upgrading and trouble-shooting applications. Since hosting takes place in a remote location, schools can use legacy and low-end equipment to run almost any program, resulting in long-term savings on equipment costs. Each student and teacher has his/her own virtual desktop. The costs range from $15 to $69 per student, and $99 to $203 per teacher, for a range of services that may include basic tools, curriculum library, productivity tools and professional development tools.

Where most technology investments take place through the district or school, the State e-Learning Framework Scenario features a state role for creating a singular environment in which to deliver support for achieving state standards. Three components are offered: administrative data on educators and students; a customizable portal workspace for every teacher and student; and standards-based curriculum and instruction support. A number of larger, more affluent districts purchase similar packages at an approximate cost of $20 per student. A statewide system, made available to every district, would require an initial investment of $9 to $11 per student (based on a statewide student population of one million students), and $3 per student in subsequent years.

Each of the alternative scenarios is discussed in more detail, including the advantages and disadvantages, on the following pages. First, here is a discussion of the methodology used to develop the cost estimates for each scenario.

Methodology

The authors developed technology targets for various school levels in order to estimate the costs of investing in K-12 technology infrastructure. These targets, detailed below, were used to cost out each of the primary investment scenarios. While costs for media centers and administrative computers remained fixed across each scenario, costs for computer labs, faculty laptops and the costs per computer varied as necessary across different scenarios. For example, faculty laptops are included in most scenarios, but not in the Thin Client Scenario.

Target Technology School Set-Up

	Elementary Grades K-5, 450 pupils, 22 classrooms	**Middle School** Grades 6-8, 700 pupils, 42 classrooms	**High School** Grades 9-12, 750 pupils, 47 classrooms
Administrative Computers	3	5	10
Servers	2	3	3
Faculty Lap Tops	22	42	47
Classroom Computers[14]	65	100	150
Computer Labs[15] (25 computers per lab)	1	3	4
Total Student:Computer Ratio	5:1	4:1	3:1
Media Center Digital video cameras Digital cameras Video editing complex[16] Projectors DVD-ROM Tower CD burners	 2 2 1 2 16 stack 2	 2 4 2 3 24 stack 3	 4 4 3 3 24 stack 3
Classroom Printers[17]	22	42	47

Classroom TV and VCR	22	42	47

Based on data from the National Center for Education Statistics, the authors assigned the following characteristics to schools. Elementary schools serve grades K-5, with a student population of 450 and 22 classrooms. Middle schools serve grades 6-8, with 700 pupils and 42 classrooms. High schools serve grades 9-12, 750 students and 47 classrooms. It is understood that actual schools differ in varying degrees from these school descriptions. Schools, districts and state agencies should take into account these "target" school descriptions when using the information in this report.

This model assumes the following:

- All classrooms are connected to the Internet via high-speed dedicated lines (T1, T3, ISDN, cable).
- All classrooms have a telephone at the teacher's desk.
- All teachers and students have email accounts.
- All administrative and classroom computers are connected to the local area network, which is connected to the district's and/or state's educational wide area network.

Because each school and district is unique with respect to the quality and functionality of its existing equipment, cost estimates for upgrading and replacing the installed base assume that schools are starting at ground zero, i.e., no equipment base is assumed. In addition, the projections reflect a single, up-front investment, whereas in reality most schools will phase in purchases over a period of three to five years. See Section V for more information about how states handle capital expenditures for technology.

Be aware that the cost estimates in this report are for equipment only, and do not include estimates for networking/wiring, professional development, technical support, or any other costs associated with the full use of technology. With the exception of the Education Service Provider Scenario, software costs are not included in the estimates.

Enhanced Desktop Scenario

Most of the current installed base consists of traditional desktop computers, but in many situations the equipment and conditions are less than ideal. This scenario uses desktops to populate the Target Technology Set-Up described in the preceding Methodology section. Low and high estimated costs are given for each school level to give decisionmakers a better sense of what they may expect to spend, depending on the number and size of elementary, middle and high schools in their district, region or state.

Advantages

Desktop computers are a familiar commodity in nearly every school – a fact that offers significant advantages over new alternatives.

- Servers and other peripherals are configured to support desktop computers.
- Technical support staff are knowledgeable about desktops.
- A significant portion of the workforce has been trained to use desktops.
- Few surprises or unexpected costs.

Disadvantages

- Require more space than newer alternatives.
- Place demands for upkeep and maintenance on technical support staff and/or teachers.
- Life span averages five years or less.
- Not portable; difficult to move.

Enhanced Desktop Technology Costs

	Elementary Low Cost	Elementary High Cost	Middle School Low Cost	Middle School High Cost	High School Low Cost	High School High Cost
Administrative Computers						
Computers	$4,713	$8,229	$7,855	$13,715	$15,710	$27,430
Printers (Laser)	$1,458	$3,252	$2,187	$4,878	$3,645	$8,130
Servers	$5,004	$8,000	$7,506	$12,000	$7,506	$12,000
Faculty Laptops	$48,554	$48,554	$92,694	$92,694	$103,729	$103,729
Classroom						
Computers	$68,120	$102,115	$104,800	$157,100	$157,200	$235,650
Printers (Inkjet)	$3,696	$3,696	$7,056	$7,056	$7,896	$7,896
TV/VCR	$15,400	$15,400	$29,400	$29,400	$32,900	$32,900
Computer Lab(s)						
Computers	$39,275	$68,575	$117,825	$205,725	$157,100	$274,300
Scanner	$210	$596	$630	$1,788	$840	$2,384
Printer (Laser)	$729	$1,626	$2,187	$4,878	$2,916	$6,504

Laptop Scenario

Description

In this scenario, patterned after Beaufort School District in South Carolina, laptops are provided for each student in grades 4-12. Grades K-3 have a more traditional set-up; i.e., a number of computers in each classroom. The classrooms for 4th through 12th grades are very different from the traditional classroom. Instead of desktop computers, everyone in the classroom, including the teacher, has a laptop. To accommodate the laptops, the classroom requires wiring to the Internet and two printers on a local area network. The classroom also has a television monitor with computer hook-ups, allowing students to make presentations directly from their laptops.

The laptops offer students a large amount of memory, myriad software applications and Internet access. Laptop computers given to students create unique environments in the classroom. Teachers have to adjust their teaching style and methods to the fact that students have ongoing access to significant computing power at their fingertips. Schools must adjust their hardware configurations as well. With the amount of processing power in the laptop of each student, powerful network servers are less important. On the other hand, demand is higher for Internet access, printing capability and presentation capability.

Background

Beaufort School District in South Carolina first got the idea for this project from the Microsoft project, Any Time, Anywhere Learning. The district set up a foundation that provides financing for those students who wish to participate in the program. The system is not mandatory but instead offers computers to students who wish to participate. Students must pay some portion of the cost for their computer. Help is available from the foundation for those students who are eligible for free or reduced price lunches.

Schools start the program in the 6th grade. At this time, they feel it is easier to keep students with access to the laptops in classes with others with laptops. Schools have seen a real increase in the need for printers in classrooms with laptop students along with increased need for Internet access, electrical outlets and presentation equipment. The district's newest units cost $1,720 from Toshiba and are Pentium III's @600mhz with CD-ROM, Microsoft Office and a carrying case.

Advantages

- The Beaufort program works well for low-income students, who have shown a marked improvement in performance

- Unlimited computer access
- Students can work on a document at multiple sittings, across class periods, at school or at home
- Gives students more opportunities to engage with learning materials and pursue interests; i.e., play a more active role in their education

Disadvantages

- Expensive to provide computers for students
- It takes time and effort for teachers to adjust their teaching to use the technology effectively
- Repairs, maintenance and theft add to the costs
- Demand for printers, Internet access and software packages increases

Laptop Scenario Costs†

	Elementary Low Cost	Elementary High Cost	Middle School Low Cost	Middle School High Cost	High School Low Cost	High School High Cost
Administrative Computers						
Computers	$4,713	$8,229	$7,855	$13,715	$15,710	$27,430
Printers (Laser)	$1,458	$3,252	$2,187	$4,878	$3,645	$8,130
Servers	$5,004	$8,000	$7,506	$12,000	$7,506	$12,000
Faculty Laptops	$48,554	$48,554	$92,694	$92,694	$103,729	$103,729
Student Laptops	$331,050	$331,050	$1,544,900	$1,544,900	$1,655,250	$1,655,250
Classroom						
Computers	$62,880	$94,260				
Printers (Inkjet)	$7,392	$7,392	$14,112	$14,112	$15,792	$15,792
TV/VCR	$15,400	$15,400	$29,400	$29,400	$32,900	$32,900

† Speed and quality of equipment are the variables that differentiate the Low Cost and High Cost estimates.

Thin Client Scenario

Description

Thin client computing is a broad term referring to a network-based approach to information processing. The school's network stores all software and files; students and teachers use relatively inexpensive and bare-bones workstations to access software and files directly on the network server, rather than downloading them to the individual's computer. The thin client hardware device transmits images to its screen from the server and permits input and output. These devices do not usually have a hard drive, CD-ROM drive or expansion slot; instead they rely on network servers to run program applications and store data. Thin client software accesses most operating environments, including Java, Microsoft Windows, Legacy and UNIX, and permits local printing, audio and serial device support.

A chief benefit of thin client computing, beyond the low cost compared to a PC, is the lower cost of support and maintenance. Upgrading software is easier because software resides on the server only. Rather than loading an upgrade to each PC in the school, only the servers require attention. In addition, the desktop hardware life cycle is longer than that of a PC (or "fat client") because it has fewer parts and requires less operating speed and memory capacity. Legacy desktops that cannot handle newer, memory-hungry software programs can provide years more service when converted to thin clients. Some software applications, however, are not suited for thin client computing environments.

Thin clients may be used in conjunction with Web-based computing, in which information related to school, classroom and student work is accessible via the Internet anytime, anywhere. In such a case, the thin clients may be referred to as Web appliances. Some schools elect to lease services from an Education Service Provider (EduSP), such as Learningstation.com, which provides schools with Web-based content, software and other services for a fee. Alternatively, the school can run its own software applications housed on the school's network.

Background

Those charged with developing an effective education system should invest in the most robust network infrastructure possible, says Kim Jones, vice president of global education and research at Sun Microsystems. Such a system would include 100Mbps Ethernet and a T1 connection to the Web for every classroom, robust servers and a reliable network in every school. By contrast, thin client proponents say, investing in fat clients means dealing with obsolescence, continually training personnel to use hardware that is soon obsolete, and limitations on using the best available software due to platform incompatibility. In the next five years, Web-enabled devices, including mobile devices such as Webphones and handhelds, may well outnumber computers networked to the Web.

More and more schools will be using thin clients connected to Education Service Providers (EduSPs) for software applications and content, according to James Frazee, associate director of instructional technology services at San Diego State University. "I definitely think that's where it's heading. Thin clients are very good at keeping up-time where it needs to be. They are very affordable, although the initial outfitting of servers and network gear can be costly."

The Sweetwater Union High School District in Chula Vista, Calif., where Frazee was IT director until recently, uses switches (as opposed to hubs), which cost $2,000 to $2,500 each. Special cards are required to tie into the fiber optic network. Frazee notes, "The thin clients and server are not the only costs – you need licensing, network gear necessary to get it operating in a fast and efficient way, and you need human resource expertise to keep the network and server side software up and running."

At Lexington School District in rural North Carolina, the initial foray into thin client technology at Lexington High School proved disappointing. Their subscription to an EduSP service at $300 per computer per year was "a pretty good deal because you don't have to buy the software," says Technology Director Johnnie Van Roekel. Unfortunately, the school lacked the bandwidth to take full advantage of the system. ISDN service is not available and the cost of putting a T-1 line into the school made the EduSP deal cost-prohibitive. The T-1 frame relay from the district to the school was insufficient to use all the applications their subscription afforded. "Kids would get on and it would lock up," recalls Van Roekel. Eventually, however, Van Roekel intends to "use the thin clients as a local server metaframe network only" with Internet access.

Advantages

- Lower total cost of ownership than traditional desktops
- Simplified support and maintenance
- Better system availability (less downtime)
- Enhanced sharability (no local data)
- Extends life of legacy desktops
- Teachers are burdened with fewer administrative and technical support tasks
- Scalable
- When connected to the Web, offers anytime, anywhere learning from any machine in the network

Disadvantages

- Initial costs for servers and network devices can be substantial

- Web-based solutions require large bandwidth, which can be costly for schools
- Does not readily accommodate older, 16-bit software, which many schools own and use often
- Network reliability and capacity may need to be enhanced
- Video, graphics and applications that require heavy computing power (e.g., Adobe PhotoShop) are not well suited to thin-client architecture

Costs

The Gartner Group estimates that thin clients can save businesses up to 26% of the total cost of desktop ownership. The savings accrue not so much with the initial investment, but over the life of the machines and their use. The total cost of ownership is low primarily because ongoing maintenance and support is simplified.

Thin Client Scenario Costs†

	Elementary Low Cost	Elementary High Cost	Middle School Low Cost	Middle School High Cost	High School Low Cost	High School High Cost
Administrative Computers						
Computers	$4,713	$8,229	$7,855	$13,715	$15,710	$27,430
Printers (Laser)	$1,458	$3,252	$2,187	$4,878	$3,645	$8,130
Faculty Laptops	$48,554	$48,554	$92,694	$92,694	$103,729	$103,729
Classroom						
Server Bundles	$98,990	$287,445	$137,630	$429,830	$294,830	$452,546
Printers (Inkjet)	$3,696	$3,696	$7,056	$7,056	$7,896	$7,896
TV/VCR	$15,400	$15,400	$29,400	$29,400	$32,900	$32,900

† Speed and quality of equipment are the variables that differentiate the Low Cost and High Cost estimates.

The preceding scenarios described ways to update computer equipment. The following two scenarios describe ways to maximize the potential of education technology, regardless of the type of equipment used. Consider them as "overlays" to the installed base of equipment.

Education Service Provider Scenario

Description

Education Service Providers (EduSPs) essentially allow schools to rent, not buy, software and let others do all the application hosting work. EduSPs offer a potential solution to those who want technology services but believe schools should not be in the business of building and managing internal information technology operations. Content and software applications are available for schools looking to outsource, or "e-source," their technology functions, thereby freeing up staff and resources for teaching and learning.

An Application Service Provider (ASP) is a company that hosts a software application remotely and lets customers use it via the Internet or a private network on a subscription basis. EduSPs specialize in the education market. A subscription to an EduSP may include one or all of the following:

- Internet access
- Email
- A portal or window to the Internet customized to the school and other system users (teachers, students, administrators)
- Productivity software, such as Microsoft Office

- Educational software, such as online tutorials
- Electronic library facilities
- Curriculum management software
- Collaboration tools
- Professional development software for teachers
- Course and lesson plan tools, databases
- Remote access (for authorized users away from the school site)

Fees are typically based on the number of leased "seats" per application.

Examples of EduSPs currently serving the K-12 market include AOL, Blackboard.com, iMind, LearningStation.com, MediaSeek.com, Net Schools, OpenSchool, Oz New Media, Quiz Studio, SRI and Vantage Technologies.

Background

ASPs burst on the scene in the late 1990s and are expected to take in an estimated $2 to $22 billion in revenues by 2003. Businesses embrace ASPs as a way to avoid up-front costs and the trouble of upgrades. Additionally, smaller companies use ASPs to get access to the same high-end, high-powered software previously affordable only to Fortune 500 companies.

"In many ways, application service providers are doing for software what the Internet has already done for data – making software applications universally available, affordable and ubiquitous," says Traver Gruen-Kennedy, chairman of the ASP Industry Consortium.

Not all ASPs offer a full range of services. Schools should specify the level of customer support they expect from their provider, and investigate the provider's system and data security. Often ASPs will partner with other organizations to deliver all-in-one packages to customers. For an education customer, such a package may include Internet access, email, hosting of student information and test data, Web-based assessment and testing systems, online encyclopedia and other information resources, teacher professional development courses, and more.

ASPs are likely to have a positive effect on technical support and maintenance costs. School users access applications via a network using standard browser software, so older machines can be pressed into longer service. Too, most Web browsers require little maintenance.

Tips on selecting and evaluating an ASP are available through the Application Service Provider Buyers Guide (www.allaboutasp.org) at no charge.

Advantages

- No need for servers to run applications
- Reduces need for IT support staff in schools
- Replaces the costs of software and upgrades with a flat monthly fee
- Many ongoing operational and maintenance functions transfer to the EduSP
- Applications can be deployed quickly
- No problems with PC compliance, software compatibility or upgrades
- Easily scaled up
- Lower total cost of ownership
- Access to security, back-up, recovery and support services

- Users can access educational applications over Internet from home and community centers
- Most advantageous to small schools or those with limited IT budgets
- Around-the-clock access to software and documents
- One-stop software licensing
- Time and task tracking of software usage
- Maintains a uniform, equitable desktop for all users

Disadvantages

- Not all traditional client/server software is available in the ASP format
- The school must be connected to the Internet through a high-speed connection
- Heavy bandwidth is necessary, which can be costly to schools
- Concerns about reliability and security

Costs

The ASP Industry Consortium estimates that ASPs can reduce an organization's information technology costs by as much as 30% to 60%. Any computer, even older models, can be used to access the Internet and the services of an EduSP. Below, the cost of using an older PC to run an e-source application is compared to equipping an in-house desktop PC to run a similar application.

LearningStation Server Access Account (SAA) Cost Comparison

New Computer	LearningStation SAA
$1,300 mid-grade Pentium	$399 per SAA
$250 minimum software	Software included
$250 Internet/E-mail	Internet/E-mail included
$2,000 support	Support included
3 year total without training = $4,300	3 year total with training = $1,197

Source: LearningStation.com

Primary savings come from outsourcing applications support, as well as bypassing the need to configure, install, manage and maintain applications.

LearningStation provides the following service levels.

For students:

Classroom Basics	$15 a student
i-Curriculum Library	$20/$30/$40 a student (3 levels)
Productivity Tools	$14 a student

For teachers:

Teacher Tools	$99 a teacher
Productivity Tools	$54 a teacher
Professional Development Tools	$50 a teacher

State E-Learning Framework Scenario

Description

The Massachusetts Department of Education and partner organizations are developing Virtual Education Space (VES), a program designed to facilitate standards-based teaching and learning using Web-based tools, resources and services. VES is intended to provide every Massachusetts public teacher, student and parent with his or her own *virtual* PC with anytime, anywhere access from any Internet browser. By logging on to their VES workspace, teachers will have access to all state and district curriculum standards that apply to them, a stored database of lesson plans and other standards-based content resources. Teachers will be able to use email, discussion groups and message boards to communicate and collaborate with peers. In addition, teachers can use their customizable workspace for instructional planning, assignments, student assessment and attendance tracking.

Students will be able to use VES to get to their assignments and documents from any Internet browser at home, school or elsewhere. They can work on projects or documents and view their portfolio of completed work. Parents will be able to use VES to view their child's homework assignments, learning objectives and academic progress. In effect, VES is a statewide, public-controlled Education Service Provider.

Several states offer Web-based information on standards, school and student performance and more. As envisioned, VES is one of the more comprehensive efforts along these lines but is not yet fully operational.

Background

While a number of large school districts are devising technology infrastructures for districtwide use, VES is the pioneer state framework for aligning standards with online curricula, instruction, communication and productivity tools. Although the basic environment is the same for all participants, school districts have the option to customize VES to meet their particular needs.

The state of Washington is partnering with Massachusetts on the design and development of VES. Other states, including New York, Wisconsin, Oregon and New Jersey, are considering sharing VES resources and costs. The potential exists for sharing costs across any number of states to develop an integrated, scalable environment that is publicly owned and customizable at the state and district levels.

VES developers estimate that $100 million could lead to the creation of a self-sufficient system of online public tools that states could use or customize. In testimony before the Web-based Education Commission, Massachusetts Education Commissioner David Driscoll urged the U.S. Congress to consider investing $100 million in VES to accelerate nationwide adoption and reduce total system costs.

In the 2000-01 school year, a VES prototype with the educator tools are available to all K-12 public school teachers. Forty-four school districts are targeted for peer-to-peer training and adoption. In the following school year, VES will be available to all public school teachers, students and parents.

Advantages

- States that opt in to VES will avoid startup costs associated with building a system from the ground up and can direct resources instead toward customization
- Promotes student achievement through standards-based curriculum alignment, assessment and instructional design tools
- Web-based delivery of resources and tools is less expensive than a PC-delivered system
- Promotes sharing of resources and ideas targeted to state and district standards
- Students, teachers and parents can access their virtual workspaces anytime, anywhere an Internet browser is available
- A state-supported framework allows for economies of scale in hardware and software acquisition
- Districts in states that adopt a statewide e-Learning platform can exert leverage on their technology expenditures
- Educators will be able to focus on Web-enhanced teaching and learning instead of technology research and systems integration
- A state framework harnesses the system efficiencies of curriculum standardization as a tool to support the best practices of teaching and learning, rather than aiming for the lowest common denominator
- A multi-state public e-Learning platform would de-fragment the existing market, enabling the industry to focus on content and service enhancements rather than user acquisition

- Most of the advantages of a district-purchased Education Service Provider apply, with more control, lower costs and better integration with state standards

Disadvantages

- Requires an up-front commitment of funds, staff and time, which may necessitate legislative approval, a new funding mechanism and/or an administrative entity
- Requires inter-district cooperation and state leadership that may not already exist
- Privacy and security concerns need to be addressed
- Requires ongoing technical support, administration and content updates
- Quality and speed of Web access, especially in remote areas, could hamper system performance
- Districts may prefer their own system over a state system
- Educators may choose not to use it
- With little or no precedent, states face uncharted territory in such a venture

Costs

The Massachusetts Legislature appropriated $10.7 million over five years for VES design and development, plus $35 million over four years in implementation grants to school districts. A strong state technology infrastructure makes VES feasible. Massachusetts is in its fifth year of a five-year, $19 million project to build enterprise administrative systems and recently invested $9 million in its statewide networking infrastructure. The Massachusetts Department of Education and the nonprofit entity managing VES are interested in sharing the components of VES with other states at no charge as a publicly owned platform, in the interest of better purchasing power when seeking new development options from vendors and sharing standards-based tools and resources.

State implementation costs would include the design and development of customized resources linking state and district standards to curriculum and instruction resources; data management; training and professional development costs; and user support. If not already in place, the state and districts would incur costs to develop the infrastructure necessary to deliver VES to participating districts and schools. This would include Internet access for all classrooms, computers or Web appliances for student and teacher use, and perhaps a plan to provide equitable home or community access to students and parents without Internet access and equipment.

In the case of Massachusetts, in order for districts to receive state approval of their local technology plan, which is required for e-rate and grants, they must implement a plan that achieves the following outcomes by 2003:

- Create a 5:1 student-to-computer ratio
- Connect 100% of their classrooms to the Internet
- Employ an average of 1.5 FTEs of technical and curriculum integration support per building
- Maintain data that meets state requirements
- Ensure that students and teachers have access to the Internet outside of school.

Districts that meet these standards will be well-positioned to benefit from a pervasive public e-learning system such as VES. The costs to districts to maintain these standards are estimated at $250 per student annually.

States can expect to spend $3 per student annually to benefit from a VES-like e-learning system. In addition, system implementation (professional development in particular) should be funded at 3-4 times the system's costs, or roughly $10 per student annually.

V. Additional Factors to Consider

State Approaches to Funding Education Technology

Capital investments in schools, including facilities and upgrades, historically have been funded at the local level. Recently though, states have begun to step in and fill the gaps left by insufficient funds in schools and districts. States are being sued to provide a "thorough and uniform" education, including adequate school facilities. Demands for the equitable distribution of technology are likely to arise as well, putting states in the position of providing uniform access to technology tools in education.

State funding options include direct aid, matching grants, aid for debt service and state loans. (For a detailed, state-by-state breakdown, see Appendix D.) Local funding options include bonds, earmarked funds for technology and partnerships with businesses and grantsmanship. For more information on funding approaches, see the ECS report, *Making Better Decisions About Funding School Facilities.*

The most common method states use to fund education technology is to earmark state tax dollars. In California, Ohio and South Carolina, for example, legislators have appropriated relatively large amounts of money for increasing accessibility to technology, improving teachers' use of technology and assisting administrators in developing networks that will help with student records and other types of information.

States are also funding technology by establishing partnerships with private foundations, creating grant programs and offering some loan opportunities. Alaska and Idaho, for example, work with two private foundations that support the role of technology in education. Since 1997, the Alaska Science and Technology Foundation has provided more than $5 million to improve connectivity in schools throughout the state. In Idaho, the state has received grants totaling nearly $80 million from the J.A. and Kathryn Albertson Foundation for the purpose of improving the use of technology in the classroom through better computers and more professional development.

Some states – notably Indiana, Massachusetts and Pennyslvania – have authorized specific amounts of money to be distributed to districts and schools through competitive grant programs. The Indiana legislature has allocated $55 million to the Technology Plan Grant Program, which distributes money to districts on a per-pupil basis. Massachusetts and Pennsylvania have established a competitive process that has a non-specified amount attached to each grant. Massachusetts has set aside $10 million for improving connectivity in schools, and the legislature is considering appropriating more money for hardware and professional development. Pennsylvania has so far made only $1.8 million available – and only for professional development grants.

Another approach that states are using to fund education technology is loan programs. The Illinois legislature, for example, has created a $60 million program that allows schools to borrow money for technological improvements at below-market rates.

Still another source of funding for education technology is the federal government. The Technology Literacy Challenge Fund (TLCF) is a five-year, $2 billion competitive grant program established by the Clinton administration that assists schools in high-poverty areas to improve their technological capacity. Several states – including Mississippi, North Dakota, Rhode Island and Tennessee – rely heavily on this federal support. In Rhode Island, for instance, TLCF is approximately $2.25 million, which represents about 65% of state dollars appropriated for education technology. In Tennessee, TLCF contributes $6 million to state efforts to improve education technology – representing more than 80% of state dollars earmarked for this purpose. Without federal support, these and other states would not have the ability to improve the use of technology in their schools.

Finally, it is important to note that some states provide no financial support for education technology. States such as Colorado, Connecticut and Michigan have articulated their role in supporting technology in schools as being primarily facilitative or supportive, and therefore only encourage local districts and schools to seek out money from TLCF, other grants and philanthropic and/or private donors.

In most cases, states combine a variety of methods in order to fund education technology. It is not uncommon to see state legislatures earmark specific dollars for technology, have relationships with private or nonprofit agencies, offer loans to districts to support the technology infrastructure and also use TLCF and other federal resources. As technology continues to have an important role in educating our youth, states will continue to confront the issue of how to pay for education technology. How much this will cost and where the money will come from will be an ongoing concern for legislators and educators alike.

Total Cost of Ownership

Overview

The introduction and integration of technology into our nation's classrooms is not new. In the past, we have seen the introduction of lantern slides, tape recorders, movies, radios, overhead projectors, reading kits, language laboratories, televisions, VCRs, computers and multimedia. However, the exponential growth of the Internet has initiated a billion-dollar commitment to connect schools and integrate technology use across all areas of the curriculum.

States continue, however, to underestimate the costs of education technology by reporting only the capital cost of acquisition rather than the Total Cost of Ownership (TCO), which includes all expenses associated with deployment, maintenance and troubleshooting, regardless of whether a district owns or leases the hardware. In fact, the estimated annual cost of operating a computer in the K-12 environment is just over $2,000 per year after the initial investment.

TCO also must include calculations of other unbudgeted or unforeseen costs that may substantially affect a district's budget, including: asbestos/lead abatement, computer downtime, ergonomically correct furniture, improved ventilation systems, increased utility costs, Internet charges, teacher professional development, security, software, technical support and upgraded electrical capacity.

TCO will also vary based on how computers are used, network design and the formula used to compute costs. These overall, long-term costs will be substantial and will vary according to district size, geography, the age of existing infrastructure, staffing and school management.

Many district technology budgets only address the acquisition cost of hardware and software, which is just 25% of the actual lifetime cost of technology integration. School district technology costs can and should be broken down over a five-year period into the following categories:

- Hardware and software – 25%
- Management – 21%
- Support – 16%
- Development – 5%
- Communications – 4%
- User self-help – 21%
- Downtime – 7%

According to QED's preliminary 1999-00 Technology Purchasing Forecast, the average cost per student broken down by the soft costs of technology are:

Hardware	$ 48.86
Software	$ 12.10
Supplies	$ 5.58
Training	$ 11.85
Service/Support	$ 12.26

Internet	$ 7.52
Networks	$ 29.76
Other	$ 10.55
Total	$138.48

This is considerably less than the $300 per student estimate, or 5% of total education spending that some experts feel is necessary for adequate integration of education technology. This estimate is also nearly five times the amount currently being spent in most districts (Chaika and Hopkins, 1999).

Even as instructional technology spending continues to increase in U.S. schools, the low percentage of total spending reported for support and training suggests that schools have yet to factor in the Total Cost of Ownership, and will therefore be unprepared to fully support classroom computers. According to CoSN's 1990 report, *Taking TCO to the Classroom,* districts that have already invested significantly in wiring their classrooms only spend between 2% and 4% of their overall budget on technology. Such an approach – categorical, one-time expenditures that treat technology as a capital expense rather than as an ongoing, continual cost of business and service – will leave districts unprepared to meet the demands of successful technology integration.

Professional Development

Unless educators are provided with adequate support and training to use technology effectively as a teaching and learning tool, the potential benefits of educational technology will not be fully realized.

Districts have consistently failed to provide adequate funding for initial and ongoing technology professional development. Ongoing efforts are necessary due to rapidly changing technology, differing levels of practitioner expertise and as new hires join the organization. Technology training must be continuous and consistent rather than a "one-shot" basic introduction, which seems to be the norm in many schools and districts. Also, training is often focused on the acquisition of technology skills rather than how to integrate the technology into teaching. As a result, educators may encounter difficulty in applying their new skills in the classroom.

As of 1997, only 15% of U.S. teachers had received at least nine hours of education technology training (Healy, 1998). In fact, according to the Milken Exchange on Education Technology's 1998 report, *Progress of Technology in Schools,* 40% of all teachers have never received any technology training whatsoever. However, the outlook is improving. The amount of funding earmarked for teacher training in technology is growing, with an average of 17% being spent in the 1999-2000 school year. Unfortunately, this figure remains well below the recommended 30% recommended by technology experts.

Clearly, the potential that education technology brings to the classroom will continue to be minimally developed until practitioners receive adequate training and technical support. Districts must make a conscious effort to shift their focus from hardware, connectivity and rudimentary technology skills to the full integration of technology and curriculum.

There has been a proliferation of businesses and organizations offering technology training in recent years and providing administrators an array of choices from which to choose. Additionally, many innovative districts have implemented replicable programs.

Technology professional development can involve training in specific areas such as productivity, multimedia, Internet or technology integration specific to content areas. It can also be designed to suit varying levels of expertise, from beginner to more advanced. Following are some of the options available:

Professional Development Options

Individual	Classroom	Web-based
■ Tutorial software ■ Videotaped training ■ University or community college	■ Vendor training ■ Consultants/outsourcing	■ Free or fee-based

courses for credit ■ Long-term, one-on-one support ■ Paired teams	■ Teachers training teachers ■ On-site/Off-site	
Many districts are turning to a combination of the above options.		

Wiring and Networking Costs

As schools rely more on the Web for delivery of content and applications, demand for larger bandwidth will increase, along with networking infrastructure costs. Several scenarios discussed in this report, thin client computing and outsourcing software applications through Education Service Providers in particular, require hefty bandwidth and capable internal networks to take full use of the datastreams once they hit the building. These costs are in addition to the equipment purchase estimates.

The Universal Service Fund for Schools and Libraries, more commonly known as the E-Rate, was created by Congress as part of the Telecommunications Act of 1996 to provide discounts on the cost of telecommunications services and equipment to public and private schools and libraries. In its first two years, the E-Rate committed nearly $4 billion in funds, with 84% going to the nation's public schools, including those in poor communities most affected by the "digital divide". E-Rate funding has helped schools and libraries procure services ranging from basic local and long-distance phone services and Internet access services, to the acquisition and installation of equipment necessary for Internet access. For more detailed information, including an early evaluation of E-Rate funding and how it is helping to bridge the digital divide, see the Urban Institute's paper, "E-Rate and the Digital Divide: A Preliminary Analysis from the Integrated Studies of Educational Technology," at http://www.urban.org/education/erate.html.

A 1995 study by McKinsey & Company Inc. estimated the costs for maintaining school network links nationwide at between $4 billion and $15 billion a year, depending on the extent to which schools are fully wired (as opposed to centralizing Internet access in a computer lab).

The McKinsey study calculated the per-student cost of wiring and networking schools based on three different models:

- Networking all classrooms in the school (with a 5:1 ratio) and installing a T-1 line was estimated at a one-time cost of $965 per student and additional costs of $275 per student per year over 10 years.
- Creating a network in which only half of the school's classrooms are wired was estimated at a one-time cost of $610 per student and additional costs of $155 per student per year over five years.
- Centralizing a school's Internet access in a computer lab with 10 telephone lines would initially cost $224 per student and $80 per student per year over five years.

Another report, by CoSN, estimated the costs of wiring every classroom in the nation at roughly $500 per student.

Although lower-cost options may appear attractive, they typically leave schools with networks that have limited capabilities, including slower downloads and limits on the complexity of information that can be shared. Districts should plan to install networks that provide enough bandwidth to manage both current and future needs, especially as the use of multimedia applications increases.

A 1998 study by the non-profit group Cable in the Classroom found that more classrooms were wired for cable than those that had a telephone line. Such schools may want to consider the option of a wireless network of laptops or other portable, handheld devices. Technological advances continue to be made in the area of networking. Some options that administrators should be aware of include the following:

Satellite-based Internet access

Ideal for schools located in isolated areas

Less costly than T-1 lines
Costs include satellite dish and monthly access fee

Wireless LANs
Mobile computers connected to a server through PC-MCIA cards
Information is sent and received using infrared or radio signals
Greater flexibility
Internet connections aren't dependent on a cable hook-up
Ideal for districts facing costly infrastructure improvements
Idea for districts with mobile classrooms

Wireless WANs
Faster than a T-1 line
Require no monthly access fee
Uses radio band frequency to transmit between two points up to six miles apart
Eliminates the need for costly cable trenching and installation
Most effective in flat, rural areas where the buildings are fairly close together
May need an antenna or taller transmission tower
Cost average from $5,000 to $7,000 per building

Mobile Learning
A motorized cart that hold 32 laptop computers and a wireless network
Includes printer and charger apparatus
Uses radio transmissions and an Ethernet connection

Cable Internet Access
More than 80% of all districts are already wired for cable
Almost all new schools built today are being hardwired for cable
Coaxial cable used by cable TV provides a much greater bandwidth than telephone lines
Download speeds two times faster than a T1 line and 50-100 times faster than a standard phone line

For more detailed information see eSchool News Online's report "Connectivity: Beyond the Promised LAN." At http://www.eschoolnews.com/showstory.cfm?ArticleID=909.

Technologies are increasingly interactive, networked, faster and more portable. Handheld devices range in price from $149 to $440, with Palms leading the handheld computer market. The cheaper laptops still run about $1,500. Such portable and affordable devices allow students the ability to do more hands-on projects, online-research and visual analysis of information.

A wireless network of laptops allows students and teachers easy access to the latest technology whenever and wherever they want. Wireless networks avoid the restrictions of "hard lines" and present a viable option for schools in older buildings. However, wireless transmission rates are currently a mere 9.6Kbps to 14.4Kbps, as opposed to the average 56Kbps of desktop computers. Another drawback is that the smaller screens of mobile devices make downloading a full Web page tedious and time-consuming. Other concerns include the loss of privacy and security of information sent using radio signals.

Some schools across the country are testing experimental programs funded by such manufacturers as Microsoft, Apple and Palm (Walker, 2000).

The newly released report from the Web-Based Education Commission also sites the following future trends:

- Greater broadband access and data packet handling
- The use of multi purpose devices linked by wireless technology, for example, mobile phones, pagers and handheld devices
- Digital convergence and greater interactivity

- The establishment of technical standards for content development and sharing
- Adaptive technology
- Decreased cost of broadband

To view the report, go to http://www.ed.gov/offices/AC/WBEC/FinalReport/.

Technical Support

Even as the nation's schools continue to develop a strong infrastructure of hardware and connectivity, many continue to operate without adequate technical support. According to an article in the March 2000 issue of *Technology & Learning* magazine, a typical school support ratio is one support person for every 500 students, compared to the average business support ratio of one to 50. Inadequate technical support can result in extended computer downtime, the erosion of teachers' willingness to use existing technology and a failure to achieve the full potential of technology to improve administrative efficiency.

Some schools are turning to "one-stop" shopping or outsourcing to meet their technical support needs. For instance, St. John's Episcopal School in Rancho Santa Margarita, California, spends approximately $270 per student per year for a technology contract with an organization called Future Kids. The contract includes professional development, curriculum, instruction, equipment, technology support and integration training.

Other alternatives include taking advantage of extended-warranty arrangements, training middle and high school students to provide technical support, designating one or more teachers to help with training/technical support and establishing community and business partnerships. More and more high schools are relying on student tech support, a practice that gives students valuable training and experience while fulfilling a much-needed role in the school. Such practices are critical to the long-term sustainability of education technology operations.

Security

Security is yet another hidden cost of education technology integration. Administrators must consider the options available to protect school equipment from theft or vandalism, including alarm systems, grates on windows, updated locks, furniture to which equipment can be bolted and limits on after-hours access to the school. Schools also need to consider using software that encrypts, encodes or scrambles in order to protect sensitive data.

Student access to inappropriate material on the Internet is another critical concern for both parents and administrators. Access to Internet sites containing pornography, excessive violence, hate messages and other material deemed unsuitable for student consumption has caused some schools to utilize filtering software. Others, however, are reluctant to use software they feel filters out "cultural content" and appropriate learning content as well as unsuitable material. Another concern is loss of "academic freedom" for students and teachers.

While some districts have made independent decisions to use filtering software, the "Children's Internet Protection Act" requires schools that receive funding from the E-Rate program, the Library Services & Technology Act or Title III must now use filtering software on all computers with Internet access. No additional or new funds have been authorized to help schools pay for this additional cost. (For more detailed information see the Consortium for School Networking's Web site at http://www.cosn.org/resources/121900.htm.)

Alternatives for schools not receiving any of the above federal funding include using software filtering, adopting an "acceptable use policy" or monitoring usage. The latter two approaches have drawbacks, however. Acceptable use policies explain the rules but have no means of enforcement, while usage monitoring is an after-the-fact solution with no preventive measures.

Software and Digital Content

For most schools, funds for materials and supplies remain restricted, with little opportunity for reallocation (Alfaro, 1999). However, even with limited funding earmarked for instructional materials, there is no shortage of firms vying to supply the nation's 100,000 schools with new and improved products, including digital content aligned to state and national standards.

In 1996, there were few providers of specialized education software. However, by 1997-98 approximately $822 million was spent on K-12 software, of which $469 million went for productivity software (Fraser, 1999). Alliances between publishers and software developers have increased significantly. Thus, there are now numerous software tools from which to choose as the list below illustrates.

Educational	Teacher	Administrative
■ Art ■ Bilingual/ESL ■ Computer istruction ■ Content-specific material ■ Cross-curriculum material ■ Special-needs ■ Test prep	■ Assessment/tracking ■ Classroom management ■ Guidance/professional development ■ Presentation ■ Research ■ Testmaking ■ Web tools	■ Communications/networks ■ Desktop management ■ Internet security ■ Library management ■ Productivity/utilities ■ School district operations ■ Diagnostic

Many educational software packages are priced considerably lower than business software applications, and volume-purchasing programs are also available to the K-12 market. (See the Educational Resources Web site at http://www.edresources.com/er/spclprog/index.cfm.) Districts and schools also have a variety of purchase options, such as single-user, lab pack, network or site title and building license (unlimited CPUs).

An alternative to the outright purchase of software is to use the services of an Education Service Provider. (See ECS' recent report, *Smart Desktops for Teachers*, http://www.ecs.org/clearinghouse/18/47/1847.htm) Many vendors provide one-stop shopping for students, parent, educators and administrators. They offer customized curriculum that packages the best information from the Web and transmits it to schools via the Internet. One Cherry Hill, New Jersey school has decided to put one such company, BeyondBooks.com, to the ultimate test by moving from textbooks to a sole reliance on the company's Internet content.

Equitable Access to Technology

The digital divide appears to have narrowed; however, a sharp split between the haves and have-nots remains evident in areas such as home computer use and the quantity and quality of equipment available to students at school.

According to Quality Education Data (QED), the national average of students to computers was 8:1 in 1996-97 (EWA, 2000). However, as shown in the chart below, urban districts typically have student-computer ratios far greater than the national average. Even worse, most of the computers in such districts are too outdated to run sophisticated software (spreadsheets, database programs), play CD-ROMs or even access the Internet. Based on QED's 1996-97 data, more than three-quarters of the Detroit school system's 14,000 computers consisted of older-model computers; in Chicago, only 56.4% of the district's computers were capable of supporting Internet connections. Clearly, these students and teachers have not been afforded the same equitable education as their peers.

Chicago	16:1 Double the national average
Cleveland	15:1
Detroit	13:1
Milwaukee	10:1

Between 1994 and 1998, the portion of public schools with Internet access rose from 35% to 89%. However, schools serving large numbers of poor children remain far less likely to have their classrooms connected. In 1998, only 39% of classrooms in high-poverty schools had Internet access, compared with 62% of classrooms in more affluent schools (EWA, 1999).

As for rural areas, fewer than 5% of towns with populations under 10,000 have cable modem service (contrasted with 65% of communities with populations over 250,000). In the future, service to rural areas is expected to improve through the use of new technologies, such as satellite broadband and third-generation mobile wireless services capable of providing data rates as high as two megabits/second.

Demographic and geographic factors continue to be significant determinants of a household's likelihood of owning a personal computer and having Internet access. Such determinants include income, race/origin, household composition, parents' education level, age and region. In some cases, these same students also lack access to community centers, libraries or other organizations that provide access to technology.

The National Telecommunications and Information Administration's 1999 report, *Falling Through the Net: Defining the Digital Divide,* used 1998 Census Bureau data to provide an updated look at the current digital divide in the U.S.:

- A high-income household in an urban area is more than 20 times as likely as a rural, low-income household to have Internet access.
- A child in a low-income white family is three to four times as likely to have Internet access as a child in a low-income black or Hispanic household.
- A child in a two-parent white household is nearly twice as likely to have Internet access as a child in a single-parent white household. A child in a two-parent black household is almost four times as likely to have Internet access as a child in a single-parent black household.

Building Infrastructure

Many rural and urban schools built in the early 20th Century lack the basic infrastructure necessary for Internet connections. A 1995 report by the General Accounting Office (GAO) stated that an estimated 60% of urban schools lacked sufficient phone lines, modems, networks, conduits and other basic elements necessary for Internet access. Additionally, 52% of schools in urban fringe areas and 46.5% of school in rural or small towns reported having an infrastructure with six or more unsatisfactory technology elements. In a 1999 NCES report, "Condition of America's Public School Facilities," 29% of all the nation's public schools reported having less than adequate heating, ventilation, and air conditioning, 22% reported having less than adequate electric power and 17% reported less than adequate electrical lighting.

In addition to deteriorating and inadequate infrastructure, other factors such as building codes and asbestos abatement, increasing enrollment and escalating costs make the school modernization that must accompany technology integration extremely difficult and costly. According to the National Education Association's report, *School Modernization Needs Assessment,* an estimated $322 billion is needed for school modernization, including $268.2 billion for school infrastructure and $53.7 for education technology. The range of needed expenditures runs from $333 million (Vermont) to $50.7 billion (New York).

States and districts must also consider that the traditional school design has become obsolete in light of the growing need for different, more flexible use of space. Computer workstations and open areas for collaborative projects are examples of space requirements that require retrofitting. Wireless technology will further enable innovative approaches to using classroom space and help to extend learning beyond the classroom walls. Such considerations will come into play as states and districts build new schools to accommodate surging enrollments.

VI. Conclusion

State leaders play an important role in determining the future of education technology. Clearly, the installed base requires updating and upgrading. Trends in demographics, technology and education augur changes in the status quo that will affect the delivery of education significantly. This report presented six strategies for investing in technology in the public schools – four equipment-based scenarios and two scenarios featuring services that have the potential to change the way technology is used to enhance student achievement and educator productivity.

Decisionmakers need to make informed decisions about the next steps. In addition to the information and options presented in this report, factors to consider include:

- Changes in population and how this varies across the state
- The number of school facilities
- The condition and quality of the installed technology base
- The age and capacity (processing speed, memory) of technology equipment
- The ability of local district efforts to raise funds for technology applications.

More specifically, policymakers need to examine these decision points and policy questions:

- Does the condition and funding of the technology base in my state need attention? What indicators support this?
- If there is a technology equipment problem, what is its magnitude? Does the state have an accurate inventory of the installed technology base? How can its needs be determined?
- Who is responsible for paying for education technology? What should be the state role? The local role?
- What mechanisms can be used to fund education technology? What are some alternative strategies?
- What effects will not investing in K-12 technology have on state and regional economic stability and economic development? How can states leverage technology investments to promote economic prosperity in rural and urban areas?

ECS invites state leaders to examine carefully the options for investing in K-12 technology and to work together to forge solutions that will harness the power of technology to secure a brighter future for learners.

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Appendices

Appendix A: List of Key Terms

Apple IIe – a brand of computer made by Apple Computer.

56Kb – refers to a digital transmission speed of 56 Kilo (thousand) bits per second.

CD-ROM – a compact disk containing data that can be read by a computer.

DOS – disk operating system usually associated with personal computers (PCs).

Hardware – the physical components of an apparatus, such as a computer.

Instructional Computer – refers to any computer used for student instruction.

Internet – refers to a network of networks all running the TCP/IP protocols, sharing the same underlying network address space as well as the same domain name space, and interconnected into a network of information.

ISDN (Integrated Services Digital Network) – refers to data communication that integrates voice and data.

Local area network – refers to the linkage of computers and/or peripherals (e.g., printer) confined to a limited area that may consist of a room, building or campus that allows users to communicate and share information.

Macintosh – a brand of computer produced by Apple Computer.

Modem – a device that connects between a computer and a phone line to translate between the digital signal of the computer and the analog signal required for telephone transmission.

Multimedia Instructional Computer – refers to any computer with a sound card and a CD-ROM that is used for student instruction.

PPP (Point to Point Protocol) – refers to a protocol that allows a computer to use TCP/IP (Internet) protocols (and become a full-fledged Internet member) with a standard telephone line and a high-speed modem. See SLIP.

Processor – the part of a computer system that operates on data; also called the *central processing unit* (may be referred to as 386 or slower, 486, Pentium, all of which refer to the speed of the processing unit).

SLIP (Serial Line Internet Protocol) – refers to a protocol that allows a computer to use TCP/IP (Internet) protocol using serial lines such as dial-up telephone lines. See PPP.

T1 – refers to a digital transmission speed of 1.544 Mega (million) bits per second.

Wide area network – refers to a data communications linkage designed to connect computers over distances greater than the distance transmitted by local area networks that allows users to communicate and share information.

Windows Compatible – a personal computer that utilizes Microsoft Windows (IBM or IBM compatible computers).

World Wide Web (WWW) – refers to a system that allows access to information sites all over the world using a standard, common interface called hypertext to organize and search information. It simplifies the process of finding a site, connecting, locating the appropriate documents and downloading the information by using a browser (e.g., Netscape, MOSAIC).

Appendix B: Sources Reviewed to Estimate Installed Base of Technology Equipment

To develop an estimate of the level of technology in public school, Augenblick & Meyers undertook a comprehensive research review. They collected data sources from the Education Commission of the States'

Information Clearinghouse, the National Conference of State Legislatures and on the Internet. The following list briefly explains the sources, and states some observations, both positive and negative, about their usefulness. The list is arranged from the most useful resources to the least. [Note: Use of the term "the authors" below refers to Augenblick & Meyers, not the authors of the various reports described.]

***Education Week* (and Market Data Retrieval):**

- *Education Week*, in collaboration with the Milken Exchange on Educational Technology, publishes an annual *Technology Counts* issue that discusses issues surrounding education and provides some statistical information on computer hardware in public schools.
- The statistical data that is reported in the *Technology Counts* issue is from Market Data Retrieval (MDR), a private marketing firm that collects and publishes education statistics.
- MDR conducted a census survey of 86,600 public schools. The response rate was 48%.
- The statistics reported in *Technology Counts '99* appear reliable because of the methods used by MDR and also because it is the most recent source of information concerning computer hardware that we located.
- *Education Week's* statistics were used to develop the final set of estimated numbers in this report.
- *Education Week's* Web site is extremely useful and has the *Technology Counts '99* issue on-line.[18]

Quality Education Data (QED):

- A private marketing firm that has published statistics and data on education technology since 1982.
- Publishes an annual report titled *Technology in Public Education.*
- Conducted a census survey of 87,206 U.S. public schools in 1997. The response was around 65%.
- This report also provided useful statistics about computer hardware in public schools.
- The statistics reported by QED appear reliable because they have been reporting these statistics for 16 years and because they use a census survey that has a relatively high response rate.
- The QED statistics are an integral part of this report's final set of estimated numbers.
- The QED Web site offers some free information.[19]

Center for Research on Information Technology and Organizations (CRITO):

- Ronald Anderson and Amy Ronnkvist's report, *The Presence of Computers in American Schools*, published in 1999.
- Conducted a sample survey of 655 *public, private, and parochial* schools in 1998. Schools were sampled according to their size and how much computer technology they had.
- This report provided useful statistics and data on the level of computer hardware in U.S. schools.
- CRITO includes private and parochial schools, but this report focuses only on public schools.
- The authors chose to use the statistics calculated in this report for the breakdown of processor speed in IBM/IBM compatible computers, as the total percentage equaled that determined by QED.

National Center for Education Statistics (NCES):

- Provided two very helpful reports:
    - Survey of Advanced Telecommunications in U.S. Elementary and Secondary Schools, Fall 1995
      - Westat, through NECS' Fast Response Survey System, conducted the survey.
      - The sample contained 917 public elementary and secondary schools in the fall 1995.
      - The information was based on schools, not computers, and this was not useful.
      - We felt that fall 1995 data might be somewhat outdated.

- Stats in Brief: Internet Access in U.S. Public Schools and Classrooms, 1994-99
  - Published in February 2000, this brief only highlighted specific aspects of technology.
  - The information about connectivity was not very useful because the categories were too broad.

Education Testing Service (ETS):

- Computers and Classrooms: The Status of Technology in U.S. Classrooms, published in 1997.
- Information cited in report is from Quality Education Data (QED).
- Reports information about the level of computer hardware in U.S. schools.
- Unclear if report is for all schools or only public schools.
- The 1995-96 data may be considered outdated.

The CEO Forum:

- School Technology and Readiness Report: From Pillars to Progress, published in 1997.
- Provided limited amounts of information.
- CEO Forum's Web site was extremely useful.[20]

Milken Family Foundation and Milken Exchange on Educational Technology:

- Provided several reports that were useful in providing background information about the importance of technology in schools, including a keynote speech, state technology policies and a survey of technology in 27 states.
- Addressed concerns of technology funding and some hardware concerns.
- Milken Family Foundation's Web site was extremely useful.[20]
- State-specific data available.

Education Commission of the States (ECS):

- Provided access to its Information Clearinghouse, where additional sources of information for this report were located.
- *Harnessing Technology for Teaching and Learning*, published in 1998.
- No data pertaining to computer hardware.

U.S. Department of Education:[22]

- Getting America's Students Ready for the 21st Century: Meeting the Technology Literacy Challenge, published in June 1996.
- This report did not have data pertaining to computer hardware.

President's Committee of Advisors on Science and Technology:

- Report to the President on the Use of Technology to Strengthen K-12 Education in the United States, published in March 1997.
- Section three discusses hardware and infrastructure issues.
- The statistics and data were for 1994-95 or earlier.[23]

Paper by Robert Heterick Jr., James Mingle and Carol Twigg:

- The Public Policy Implications of a Global Learning Infrastructure, published in 1997.
- No data pertaining to computer hardware.

Paper written by Lewis Solomon:

- The Last Silver Bullet: Technology Can Save Our Schools
- No data pertaining to computer hardware.

As mentioned above, the authors examined numerous sources of information related to the subject of education technology and selected seven reliable and useful reports. Then, using data from CRITO, QED, and *Education Week's* most recent *Technology Counts* issue, the authors estimated the existing level of computer technology in U.S. public schools. The data from those three reports were used for several reasons. First, QED and *Education Week* both conducted census surveys of all public schools in the U.S. Understandably, there may be a concern about a large sampling error associated with census surveys but the sheer amount of information received from a large number of schools outweighs this concern. Second, QED, *Education Week* and CRITO are all relatively recent reports with up-to-date information. This is important because the rate of growth and change associated with technology is incredibly high and data can quickly become outdated. Third, the CRITO data provides specific information about IBM/IBM compatible processor speeds. This information will be useful in analyzing the replacement costs because we are able to identify older models according to their processor speed. Finally, the data published by *Education Week* and QED would seem more reliable because of the length of experience both organizations have in reporting education technology data.

Appendix C is a grid that synthesizes data from the seven reports most relevant to this study.

Appendix C. The Current Installed Base – Data from Seven Reports

	NCES 1995	ETS 1997	CEO 1997	CRITO 1998	QED 1998	NCES Brief 1999	ED WEEK[24] 1999
Number of computers	5.6 Million[25]	4.4 Million		8.6 Million	6 Million		8.2 Million[26]
Mean number of computers in schools	72						
Students to instructional computer		10:1	9:1	6:1	7.8:1	6:1	5.7:1
Students to multimedia computer		24:1	16:1		12.3:1		9.8:1
Mean number of students per computer				7.3:1			
Median number of students per computer				6:1			
% of schools with multimedia computers		85%			85%		
% of school computers that have CD-ROM technology				46%			
% of schools that have CD-ROM technology		54%			74%		
% of school computers that are Apple lie		19%		9%	12%		
% of school computers that are Macintosh		41%		38%	35%		
% of school computers that are IBM/IBM compatible					53%		
% of school computers that are DOS		40%					
% of school computers				24%			

	NCES 1995	ETS 1997	CEO 1997	CRITO 1998	QED 1998	NCES Brief 1999	ED WEEK[24] 1999
with a Pentium processor							
% of school computers with 386 or 486 processor				18%			
% of school computers with 286 or earlier processor				6%			
% of computers that are "other"				4%			
% of schools having access to computers connected to a LAN	77%						
% of schools that have computers connected to a LAN		38%			56%		
% of school computers connected to a LAN				48%			22%
% of schools having access to computers connected to a WAN	61%						
% of school computers connected to a WAN					23%		
Mean number of computers with Internet access per school	12						
% of school computers with Internet access	14%						
% of schools with Internet access	50%	64%	65%	90%	70%	95%	90%
% of schools with Internet access via a large bandwidth[27]				30%			
% of schools connected to the Internet that have Internet access via T1	7%						49%
% of schools with Internet access via dedicated line[28]						63%	
% of schools with Internet access via a slower bandwidth[29]				27%			
% of schools connected to the Internet that have Internet access via ISDN	3%						7%
% of schools with Internet access via dial-up connections						14%	
% of schools connected to the Internet with Internet access via a cable modem							7%
% of schools connected to the Internet that have Internet access via SLIP or PPP	23%						
% of schools connected to the Internet that have	10%						12%

	NCES 1995	ETS 1997	CEO 1997	CRITO 1998	QED 1998	NCES Brief 1999	ED WEEK[24] 1999
Internet access via 56Kb							
% of schools connected to the Internet that have Internet access via modem	81%						
% of schools with Internet access via individual/network modem				33%			23%
% of schools with Internet access via other connections[30]						23%	2%

Appendix D. State Approaches to Funding Education Technology

	Education Week's Technology Counts '99	Milken Exchange's Education Technology Policies of the 50 States (1999)[31]
Alabama	The state earmarked $3.5 million specifically for technology in K-12 schools for fiscal 2000, which begins Oct. 1.	$4.1 million earmarked for K-12 education technology
Alaska	No state dollars are dedicated specifically to school technology. Although many districts opt to spend a portion of the money, the legislature gives them for education in general on technology. Additionally, federal funds, such as the Technology Literacy Challenge Fund and E-rate discounts, help pay for connectivity. Another source of funding is the Alaska Science and Technology Foundation, which since 1997 has contributed $5 million in materials to wire schools. Districts have matched that contribution with $9 million.	NONE
Arizona	The fiscal 2000 budget, which took effect July 1, includes aid for so-called soft capital, which averages $225 a student and must be spent on any of several categories, including technology.	$2.2 million earmarked for K-12 education technology
Arkansas	The state allocated $15.5 million for fiscal 2000 for school technology.	$15 million earmarked for K-12 education technology
California	This year's legislature appropriated $151 million for education technology.	NONE
Colorado	No state dollars are dedicated to school technology. Each district can use its own funds for technology. The legislature did approve a $4.8 million pilot program in which local towns, school districts, libraries and other public institutions join and receive a matching grant to become the anchor tenants for high-speed Internet services from a telephone company or Internet service provider.	$107,000 earmarked for K-12 education technology
Connecticut	No state dollars are allocated to school technology this year.	NONE
Delaware	The legislature passed a bond last year that will provide $13 million over a three-year period. Schools will receive $5 million for fiscal 2000, which began July 1.	$12.1 million earmarked for K-12 education technology

	Education Week's Technology Counts '99	Milken Exchange's Education Technology Policies of the 50 States (1999)[31]
Florida	The state budget for technology in fiscal 2000, which began July 1, is $63.4 million.	$88 million earmarked for K-12 education technology
Georgia	In fiscal 2000, which began July 1, the lottery-derived dollars total $32.8 million, or $23.10 per pupil. The legislature also allocates some money from the state's general fund for school technology. This year, the state is spending $15 million to pay technology specialists to work in local districts. The money will be enough to hire one specialist for every four schools.	$60 million earmarked for K-12 education technology
Hawaii	The governor's budget for fiscal 2000, which began July 1, included $9.3 million for school technology – $1.8 million for classroom computers and $7.5 million for wiring and related construction.	$23.5 million earmarked for K-12 education technology
Idaho	Idaho lawmakers approved $10.4 million for K-12 education technology and $1 million for technology-related teacher training at the state's universities in fiscal 2000, which began July 1. A three-year, $80 million grant from the J.A. and Kathryn Albertson Foundation is giving this effort a major boost.	$10.4 million earmarked for K-12 education technology
Illinois	Lawmakers earmarked $48.8 million for education technology this fiscal year. They also appropriated $12 million for expanding the capabilities of Linc-On, a network run by the state education department that is currently hooked to roughly 2,500 of the state's 4,000 schools. In addition, the state is in its third year of a four-year funding formula that allocates between $24.5 million and $26 million in state technology grants annually. Illinois is also expanding a revolving loan program that enables schools to borrow money to make technological improvements. The state expects to make $60 million in loans available by fiscal 2001.	$46.25 million earmarked for K-12 education technology
Indiana	In the biennium that began in July, legislators appropriated $55 million to the Technology Plan Grant Program. The money came from state gaming revenue – which includes proceeds from lotteries, riverboat gambling and horse racing. The technology grants are apportioned to local districts on a per-pupil basis. This biennium, the grants are $100 per pupil. Thirty percent must go to train teachers and administrators. An additional $21 million in gaming revenue will be used for school technology projects that improve Internet connectivity and enable interactive videoconferencing and distance learning statewide.	$27.6 million earmarked for K-12 education technology
Iowa	Through the School Improvement Technology Act, passed in 1996, the state is allocating $30 million in the current fiscal year for schools to spend on hardware, software and infrastructure.	$30 million earmarked for K-12 education technology
Kansas	The state gave each school system $12,500, plus $13.70 per pupil, to spend on technology infrastructure and training. Also, this fall, the education department plans to take to the governor's office a proposal to build a statewide computer network at a cost of $12 million.	$11.4 million earmarked for K-12 education technology
Kentucky	A total of $43.5 million is appropriated for school technology during fiscal 2000, which began July 1.	$81.4 million earmarked for K-12 education technology
Louisiana	School technology funding from the state is $14 million in fiscal 2000, which began July 1.	$25 million earmarked for K-12 education technology
Maine	Maine's telecommunications carriers must contribute up to 0.5$ of their revenue to a state universal-service fund. As of July 1, 2001, Maine's schools and libraries will be able to tap the money (expected to be $3 million) to help defray technology expenses. The legislature is appropriating $218,000 in the current fiscal year to cover the network's maintenance and operating costs.	NONE

	Education Week's Technology Counts '99	Milken Exchange's Education Technology Policies of the 50 States (1999)[31]
Maryland	Maryland lawmakers set aside $16.7 million for school technology in fiscal 2000, which began July 1. On the business front, GTE launched a three-year, $2.4 million pilot project last year to establish a "wireless school" in a Washington suburb. Students at a Prince George's County elementary school, all furnished with their own laptops, are connecting to the Internet using radio waves, not phone wires.	$13.8 million earmarked for K-12 education technology
Massa-chusetts	The state education department requested $1.5 million for central-office upgrades; $5.5 million for information-system-management upgrades; $2 million for Mass Ed Net, which provides unlimited, toll-free Internet access to some 80,000 public school educators; and $10 million for the Massachusetts Commonwealth Network, a high-speed Internet link for schools and district and state offices. The legislature approved $10 million in grants to link schools and other public agencies to high-speed Internet service. It was also considering proposals to award $35 million in grants for training and new computers, and $5 million in grants for computer learning labs in public housing complexes. In fiscal 1999, which ended June 30, the state spent $27.6 million on education technology.	$16.5 million earmarked for K-12 education technology
Michigan	The state provides no dollars to directly support education technology. Most of the money Michigan's school systems spend on technology comes from local bond issues or from federal grant programs, such as the Technology Literacy Challenge Fund and the E-rate program.	NONE
Minnesota	This year the legislature decided to give districts more flexibility to pursue their own initiatives. A total of $14.9 million was set aside specifically for technology in the biennium that began in July.	$115 million earmarked for K-12 education technology [32]
Mississippi	The state will spend $17.4 million on school technology in fiscal 2000, which began July 1. Mississippi districts have about $6.5 million in money from the federal Technology Literacy Challenge Fund. The legislature also appropriated $500,000 for Teachnett, a professional development program for teachers. Mississippi's budget also includes $2 million for the comprehensive Mississippi Student Information System to help districts keep track of achievement scores and student records.	$50 million earmarked for K-12 education technology
Missouri	The state allocated $39.2 million for technology in fiscal 2000.	$35 million earmarked for K-12 education technology
Montana	Districts primarily rely on federal grants and locally raised money to build their technology programs.	NONE
Nebraska	About $12.7 million is earmarked for school technology this fiscal year, which began July 1. Another $900,000 will come from a fund that was originally designated for making schools more energy-efficient, but for the past several years has been devoted to technology. U S West paid $627,000 for a yearlong program that prepared teachers to be technology mentors.	$5 million earmarked for K-12 education technology
Nevada	The state legislature allocated $4.2 million this biennium for school technology. The state will also spend $4 million over two years to continue establishing its State Management of Automated Record Transfer (SMART) program, a system for transferring student records electronically. Additionally, $3.5 million was appropriated to establish four regional professional development centers in Nevada.	$20 million earmarked for K-12 education technology

	Education Week's Technology Counts '99	Milken Exchange's Education Technology Policies of the 50 States (1999)[31]
New Hampshire	No state dollars are specifically allocated toward funding education technology. Instead, the state encourages schools to maximize the resources they have, whether from federal grants or local funds dedicated to technology.	NONE
New Jersey	The main state-funded program to pay for school technology gives nearly $54.5 million, approximately $42 per pupil, to districts in fiscal 2000, which began July. The state expects about $9.4 million for fiscal 2000 from the federal Technology Literacy Challenge Fund.	$53 million earmarked for K-12 education technology
New Mexico	For fiscal 2000, which began July 1, lawmakers earmarked $5 million for a technology fund established by the passage of the Technology for Education Act in 1994. And an ongoing five-year, $8.7 million Technology Innovation Challenge Grant will allow the state to launch regional technology support centers for teachers.	$4.4 million earmarked for K-12 education technology
New York	Overall, state aid to schools for education technology is an estimated $239 million for the current fiscal year, which began April 1. Additionally, the state received nearly $37.5 million from the Technology Literacy Challenge Fund in 1999-2000.	$239 million earmarked for K-12 education technology
North Carolina	The legislature has allocated $10 million of the state's $5.3 billion biennium education budget, which began July 1, for school technology purposes.	$20 million earmarked for K-12 education technology
North Dakota	The legislature voted this past spring to spend $6 million of its $540 million biennial education budget on technology-related infrastructure and teacher training. Additionally, $2 million from the Technology Literacy Challenge Fund and more than $1 million from a Technology Innovation Challenge Grant will go toward expanding the state's professional development efforts.	NONE
Ohio	For fiscal 2000, which began July 1, the legislature appropriated $139.7 million for school technology.	$54.2 million earmarked for K-12 education technology
Oklahoma	No state dollars are available for school technology in the current fiscal year. In fiscal 1999, which ended June 30, the legislature appropriated $16.4 million to school technology.	$17.8 million earmarked for K-12 education technology
Oregon	In the current biennium, which began July 1, the legislature is providing $2 million for education technology. The legislature also passed a bill in July that sets up a $50 million school technology fund financed by the state's telecommunications vendors.	$2 million earmarked for K-12 education technology
Pennsylvania	Total state spending on school technology is expected to be just over $60 million in fiscal 2000, which began July 1. Additionally, eight grants, totaling $1.8 million, were awarded this past spring to help develop online professional development resources and activities for teachers. The state also hopes to improve teacher preparation in technology through a $5.4 million initiative approved last year.	$57 million earmarked for K-12 education technology

	Education Week's Technology Counts '99	Milken Exchange's Education Technology Policies of the 50 States (1999)[31]
Rhode Island	Lawmakers set aside about $3.5 million for education technology in the state's fiscal 2000 budget. The state also received $2.25 million from the federal Technology Literacy Challenge Fund program.	$3.5 million earmarked for K-12 education technology
South Carolina	This fiscal year, which began July 1, the legislature is devoting $40 million to school technology.	$33.5 million earmarked for K-12 education technology
South Dakota	In all, the legislature is spending $5.6 million on school technology in fiscal 2000, which began July 1. The newly appropriated money comes on top of $13 million left over from last year's general education funds.	$6.3 million earmarked for K-12 education technology
Tennessee	In the current fiscal year, which began July 1, Tennessee's legislature appropriated $7.5 million for school technology. Tennessee also received $6 million from the Technology Literacy Challenge Fund grant.	$5 million earmarked for K-12 education technology
Texas	The legislature approved $2.3 million for school technology for the 2000-01 biennium, which began Sept. 1. In addition, the legislature allotted $30 per student per year, or about $117 million for fiscal 2000, to allow districts to buy software and hardware or provide professional development. The legislature also approved an additional $14 million for an ongoing project to consolidate a wide range of information on state schools – including results from state tests and management data collected from districts – into a data warehouse.	$125.6 million earmarked for K-12 education technology
Utah	Overall, the state budget includes $24.4 million for education technology programs. The state has budgeted approximately $10 million for Internet hookups and distance learning in its fiscal 2000 budget, which took effect July 1.	$24.9 million earmarked for K-12 education technology
Vermont	The state is using funds from a federal Technology Literacy Challenge Fund grant – totaling $5.25 million over the past three years – to get basic hardware into schools in impoverished areas.	
Virginia	The state's sole education technology expenditure last year was a $385,000 fee to the Milken Exchange on Education Technology. At the same time, Virginia lawmakers allotted $64 million last spring for education technology in fiscal 2000, which began July 1. In another development that could affect technology spending, Virginia lawmakers voted last spring to direct all future lottery proceeds – estimated at $300 million this year--to fund school construction and other public education needs.	$705,000earmarked for K-12 education technology
Washington	In the current biennium, which began July 1, lawmakers are spending $29 million to subsidize the network's operational costs. The legislature has also set aside in the current biennium $5.7 million for regional technical support agencies to provide troubleshooting services to people using the network.	$21 million earmarked for K-12 education technology

	Education Week's Technology Counts '99	Milken Exchange's Education Technology Policies of the 50 States (1999)[31]
West Virginia	The legislature earmarked $7.5 million for the state's elementary school technology program this fiscal year. An allocation of $8.8 million will be used to bring computers into middle and high school classrooms. West Virginia will spend almost $20 million dollars on instructional technology this fiscal year, which began July 1.	$22.6 million earmarked for K-12 education technology
Wisconsin	The state plans to spend $152 million on technology in K-12 schools during the fiscal 2000-01 biennium, which began July 1.	$35 million earmarked for K-12 education technology
Wyoming	The state's technology plan calls for spending $70 million to reach all its goals. Last year, lawmakers set aside $40 million over the next five years.	$9.2 million earmarked for K-12 education technology

Endnotes

1. The Seven Dimensions of Progress (Milken Exchange), the CEO Forum, and NCREL's new enGauge framework are among the leading tools for educators about how to use technology effectively in education.
2. See *Smart Desktops for Teachers*, ECS, 2000.
3. This section and estimates in Section IV were prepared by Augenblick & Myers, Inc., an education-consulting firm based in Denver, for the Education Commission of the States.
4. See Appendix A for a definition list of important terms discussed throughout this report.
5. The U.S. Department of Education encourages everyone to have a comprehensive view of education technology. This includes professional development, effective software, connectivity to the Internet, and the quality, and capabilities, of the computing machines. This report will focus on the two latter aspects.
6. *Education Week* is abbreviated as EW. Quality Education Data is abbreviated as QED.
7. We estimated the number of multimedia computers by taking the number of students per instructional computer times the total number of instructional computer to establish the enrollment number used by QED. We then divided that enrollment number by the number of students to multimedia computers to establish the number of multimedia computers. We then divided the number of multimedia computers by the total number of instructional computers to establish the percentage of computers that are multimedia. We then multiplied that percentage number times our estimate of 7.1 million instructional computers to establish our estimated number of multimedia computer. We did this process for both QED and Education Week data, and then averaged the two numbers to get 4.3 million multimedia computers.
8. QED estimates that 52% of school computers that are IBM/IBM compatible. In our research, we found a survey conducted by CRITO that breaks down IBM/IBM compatible computers by the processor type. We chose to use this breakdown because it is most informative, and it closely mirrors the results reported by QED.
9. More extensive trend data is available in "Trends Affecting the Condition of K-12 Public Education," *Governing America's Schools: Changing the Rules*, Education Commission of the States, November 1999.
10. "Building the Net: Trends Report 2000," Software and Information Industry Association, July 2000. http://www.trendsreport.net/
11. *Smart Desktops for Teachers*, Education Commission of the States, October 2000.
12. Cite EdMin study in Calif elementary schools.
13. U.S. Department of Education, National Center for Education Statistics, *The Condition of Education 2000, NCES 2000-602*, Washington, DC: U.S. Government Printing Office, 2000.
14. Assumes a total student to computer ratio of 5:1 or less; minimum PC configurations: Pentium III processor 500MHz, 64MB RAM, 6GB HD, with DVD device, 15-inch color monitor; minimum Apple configuration: G4 processor, 400 Mhz, 64MB, 20GB HD, DVD-ROM, 17-inch color monitor
15. Each computer lab is equipped with 25 computers, 1 scanner, 1 Zip250 drive, 1 printer; the elementary lab is general purpose; the middle and high school labs have one general purpose and the others are devoted to subject areas
16. Video editing computers require G4 or Pentium III processor, 256 MB RAM, 40G HD, 550MHz, equipped with video editing software; the complex should also include a DVD-RAM, sound mixer, high quality VHS tape deck.

17. Inkjet or laser printers
18. The *Education Week* website can be found in the reference section.
19. The QED website address can be found in the reference section.
20. The CEO Forum's website address can be found in the reference section.
21. The Milken Exchange on *Educational Technology's* website address can be found in the reference section.
22. Although the National Center for Education Statistics is part of the U.S. Department of Education, it will be listed as a separate source due to the nature and usefulness of the information provided.
23. Due to the growth factor associated with technology, any data collected before fall 1995 was considered outdated.
24. *Education Week's Technology Counts '99* reported data that was collected by Market Data Retrieval's *School Technology Survey1998-99.* Although the "% of computers connected to a LAN" was taken from unpublished tabulations of Quality Education Data's *Core School Technology Survey 1998-99.*
25. To get an estimate of the number of computers in U.S. public schools we took the mean number of computers per school and multiplied by the total number of schools indicated in the report. 72*77,853=5,605,416
26. The number of computers in U.S. public schools was not reported in *Education Week's Technology Counts '99* report, but it was published by MDR when the results of the *School Technology Survey 1998-99* were made available to the public (see MDR press release 10/31/99). We felt that it was appropriate to include this number with the *Education Week* results, since the survey was originally done in conjunction with *Education Week.*
27. Large bandwidth includes wide-band cable or wire connections that have speeds of one megabit per second (T1) or greater.
28. Dedicated line connections include T1/DS1, fractionalized T1, 56Kb, T3/DS3, and fractionalized T3 lines.
29. Slower bandwidth includes ISDN connection.
30. The NCES Brief includes ISDN, wireless connections, and cable modems in their "other" category.
31. For the purpose of this survey, only dollars that were specifically dedicated to education technology were included.
32. Minnesota, Oregon, and Virginia have biennium budgets. According to the Milken Exchange biennial funding for these three states are as follows:

Minnesota	FY98-98 $115,000,000
Oregon	FY97-98 $2,000,000
Virginia	FY95-96 $118,300,000

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