School Investments in Instructional Technology

Ronald E. Anderson
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Teaching, Learning, and Computing: 1998 National Survey

Report #8

Center for Research on Information Technology and Organizations
University of California, Irvine

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INTRODUCTION

In the 1980's, economic research on school expenditures suggested that different patterns or amounts of spending did not have major effects on student learning (Hanushek, 1989). However, a growing body of research now argues that expenditure patterns—particularly how schools spend their funds—does have consequences for teaching and learning (Hedges and Greenwald, 1996; Ladd, 1996; National Research Council, 1999). Research on such questions is difficult, and has yet to be applied to particular areas of expenditure such as how schools spend money on information and communication technologies. Yet over the past two decades, schools have been spending increasing proportions of their discretionary funds to acquire computer equipment, software, and related supplies and services (Pelavin, 1997), and they are under continuing pressure to make those expenditures count. Some policy panels are recommending dramatic increases in spending rates with the expectation that the result will be clearly improved student academic accomplishment. For instance, the President's Committee of Advisors on Science and Technology & Panel on Educational Technology (1997) recommended a 3-fold increase in public spending on technology-related resources and services.

To date, the vast majority of school technology-related expenditures has been devoted to building up the hardware infrastructure of computers, peripherals, and network connections. Much of this has been to keep up with an ever-changing market supplying newer and more capable computer-related equipment. Estimates of K-12 spending on educational technology during the early 1990s found that nearly two-thirds of all investments on technology have been for this technical infrastructure (McKinsey & Co., 1995). Beginning in the mid-1990s, American schools have been adding expenditures for Internet-access to their technology budgets. Thus the share of technology-related dollars spent for hardware may be even greater now than before Internet connections became widespread in schools.

At the same time, the widespread consensus among those in government and research who have been studying computer use in education is that effective use of educational technology depends most strongly on the human element—on having teachers and support personnel who have not only technical skills in using computers but practical pedagogical knowledge about designing computer activities that create intellectually powerful learning environments for students. The OTA Report on Teachers and Technology concluded, for example, "to use technology effectively, teachers need more than just training about how to work the machines and technical support. [They] need hands-on learning, time to experiment, easy access to equipment, and ready access to support personnel..." (Office of Technology Assessment, 1995, p. 129). The President's Committee of Advisors on Science and Technology & Panel on Educational Technology (1997) and the CEO Forum (1999) drew similar conclusions. The Department of Education's (2000) National Technology Plan makes improving "the instructional support available to teachers who use technology" a national goal. A recent TLC (Teaching, Learning and Computing) report by Ronnkvist, Dexter, and Anderson (2000) elaborates upon the critical ingredients of quality support and shows how important it is to successful technology integration.

The costs of technology implementation are not equal in different types of schools. Low-income school districts are likely to require greater expenditures due to having older facilities and higher security problems (Pelavin 1997). In addition, schools serving communities with poverty and high mobility may not be able to develop "exceptional financing methods" such as corporate donations and parent fund-raising activities. Moreover, the schools with the greatest need are the ones whose students are also least likely to have access to computers and the Internet at home.

This report will describe instruction-related technology spending of American schools and show how its pattern varies across different types of schools. The main focus will be upon differentiating software and training-and-support costs from hardware costs and to explore the implications of relative spending in these areas. One important question is whether or not the digital divide is being widened by the investment strategies taken by schools. The findings of this report move us closer to being able to answer such important questions.

SAMPLE

Our data comes from Teaching, Learning, and Computing (TLC), a national survey of schools conducted in the spring of 1998. The TLC survey involved principals, building-level technology coordinators, and a sample of teachers from a national probability sample of schools and from two targeted or purposive samples of schools: (1) high-end technology-using schools and (2) schools that were participating (or where teachers were participating) in one of 52 identified national and regional educational reform programs.

School Probability Sample

The national probability sample of schools consisted of 898 public, private, and parochial schools selected from a national database of 109,000 schools supplied by the firm of Quality Education Data (QED) of Denver, CO, a marketing information division of Scholastic Corporation. Schools were sampled according to their size (estimated number of full-time teachers of grade 4 and above) and according to how much computer technology they had (using an index incorporating ten different measures of per-capita technology presence). Initial contact letters and roster forms were sent to 898 schools, and after repeated callbacks a total of 655 schools (73%) agreed to participate. From these schools, 488 (75%) of the principals returned completed questionnaires as did 467 (71%) of the technology coordinators.

Purposive Samples

The two purposive samples were compiled from a multitude of sources. The "educational reform" purposive sample (470 schools) came from rosters compiled of 52 different educational reform efforts. The high-end technology purposive sample (258 schools) was compiled from three types of sources: publicly available information from school Web sites and books, from one high-end technology education reform program, and from the Quality Education Data database (the schools with the highest technology presence index). A total of 560 purposively sampled schools participated in the study.

Selection of Teachers

At each of the 1,215 participating schools, samples of 3 (elementary) or 5 (middle and high school) teachers were drawn through probability sampling methods, based on a systematic rostering of all or part of the school's teaching staff. Selection of teachers was weighted towards those described during the roster process as being technology users, users of student projects, and emphasizing higher-order thinking in their instruction. In addition, about 17% of selected teachers (reform program participants and principal nominations of exemplary teachers) were sampled with certainty. This differential sampling enabled us to obtain more reliable information on certain teacher populations of particular interest. Nevertheless, all analysis involving teachers was conducted by weighting teacher reports inversely to the probability of that teacher's selection in her sampled school. For further information about the data collection and sampling process, see Appendix B in TLC Report 4 (Ravitz, Becker, and Wong, 2000).

Sample Structure

Across the combined probability and purposive samples, there was a 75% response rate at the school roster stage and close to a 70% response rate at the individual respondent level. Thus the entire survey database includes information from 1,150 schools including completed questionnaires from approximately 4,100 teachers, 800 technology coordinators, and 867 principals.

The analysis in this report was based primarily upon information from the 467 technology coordinators whose schools were included in the national probability sample, although some data items from the principals' survey were merged into the technology coordinators' survey data when available. (Roughly 10% of the schools did not have a technology coordinator, in which case the "most knowledgeable person" was asked to complete the questionnaire.) Some data (e.g., Figure 6) also includes the technology coordinators from the purposive samples, so that comparisons could be made between their schools and the probability sample. Finally, the last part of the paper discusses teacher-level responses to school expenditure patterns, and those analyses come from all 4,083 teachers participating in the survey, including the 2,251 in the probability sample and the 1,832 from the purposively-sampled schools. The main analysis was limited to the probability sample because its goal was to describe or generalize to the entire population of American schools. The analysis of teacher impacts utilized the combined samples because its goal was to show the inter-relationship between school expenditure patterns and teacher practices, which in most instances is generally the same in purposive samples as it is in the more nationally representative probability sample.

Measurement

A substantial portion of the 17-page school technology coordinator survey booklet dealt with school investments in technology, and the Appendix contains the relevant survey questions. The first few questions dealt with technology support provided to teachers; for example, the number of hours per week, on average, that were spent by the school technology coordinator and by other people on each of seven different support functions. Second came a series of 13 multi-part questions asking for the number (and location) of computers, peripherals of various types, LANs, Internet connections, and the availability of various types of software. Next was a one-page matrix question asking for estimates of the amount spent "in the past two years" on items in each of 13 different technology-related categories. The respondent was asked to give the expenditures separately for school and district expenditures. The support and inventory questions deliberately preceded the expenditure questions so that they would aid in the recall of the full range of spending. Even though we only asked for spending over a two year period, and interpolated the dollar figures provided to estimate expenditures over the 12 months just prior to the survey, the inventory of equipment and software and the report of the number of hours spent on training and support made it possible to make rough estimates of overall technology investment over a five year period.

Using these methods for measuring the amount that schools and their districts spent on hardware, software, and teacher support services, numerous indicators were constructed, representing the various elements going into a school's practice of investing in educational technology.

TECHNOLOGY EXPENDITURES AND INVESTMENTS

Findings

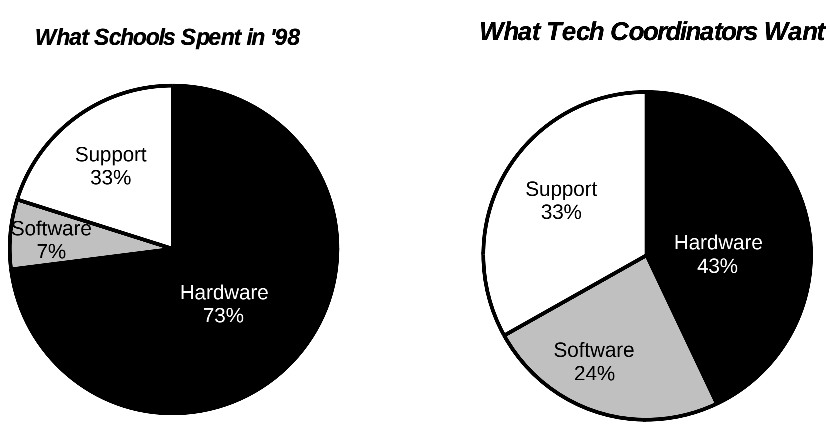
From our measures, it is possible to estimate that the total technology expenditures in FY98 for the K-12 system were about $7.2 billion. This was about 2.7% of the total educational expenditures for that year. As shown in Table 1, the average school spent $113 per year per student on technology, with only $22.5 of that for teacher support services, about $8 for software, and the remainder for hardware. Table 1 gives the expenditures per student for the more detailed expense categories under each of these three broad areas. The estimated expenditures included materials purchased, but also installation and repair costs as well as salaries and technology-related staff development costs. These estimates of technology expenditures are generally consistent with those made by McKinsey & Co. in 1995 and by Quality Education Data in 1998.

TABLE 1: PER-STUDENT EXPENDITURES IN U.S. SCHOOLS, 1997-98

Hardware	
Instructional computers	$42.40
Peripherals	5.70
Video production	1.10
Computer furniture	2.30
Local area networks	13.60
Internet	3.40
Computer maintenance	3.40
Total Hardware	82.70
Software	
Individually purchased software	4.50
Site licenses	3.40
Total Software	7.90
Support	
Salary for technology coordinator	11.30
Salaries for others providing training	4.50
Release time, training expenses	4.50
Other expenses for support	2.30
Total Support	22.60
Grand Total	$113.20

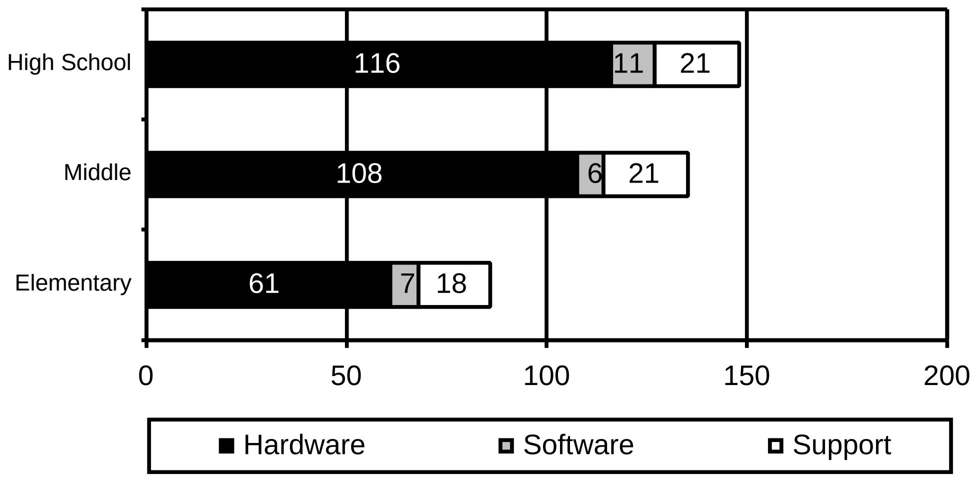
One unique aspect of our study was the ability to contrast technology expenditures with information from the technology coordinators on what they felt should be spent on each of the three expenditure categories. Figure 1 shows that while an average of 74% of the technology budget was spent on hardware, the average school's technology coordinator thought only about 40% of the budget should be spent on hardware. Likewise the technology coordinators thought that the relative amount spent on software and support should be much greater than it actually was. In this regard, it is significant that the opinions of the technology coordinators were consistent with the conclusions of several major national studies including the Presidents Committee of Advisors on Science and Technology (1997) and the U.S. Congress's OTA report of 1995.

FIGURE 1: COMPARISON OF ACTUAL EXPENDITURES WITH DESIRED EXPENDITURES



The relative amounts spent on hardware, software, and support were essentially the same for the three main school levels. Figure 2 shows the average amounts spent on these three areas separately for elementary, middle, and high schools. As can be seen, high schools spent more on technology overall than middle schools, which spent quite a bit more than elementary schools. The Figure reveals that even though high schools and middle schools spent on average quite a bit more on technology than elementary schools, they did not spend much more than elementary schools on support. In other words, elementary schools spend a higher portion of technology dollars on teacher support than secondary schools.

FIGURE 2: PER-STUDENT TECHNOLOGY EXPENDITURES (U.S. DOLLARS) BY SCHOOL LEVEL



Overall Technology Investment (Expressed as Five-Year Expenditure Estimates)

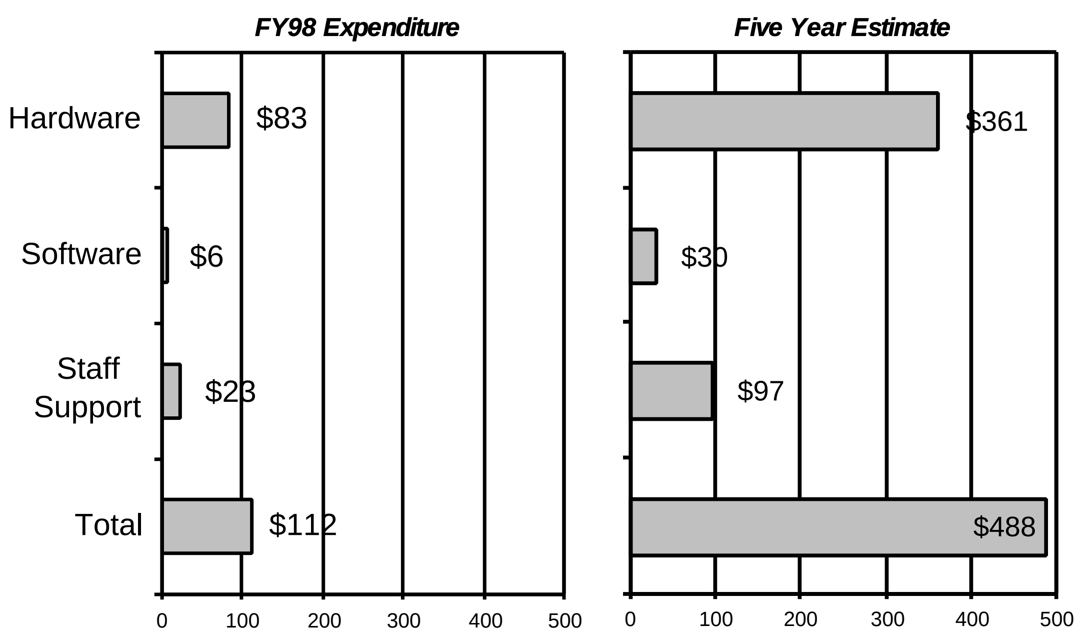
Although data on expenditures over the most recent one or two year period are useful for understanding a school's investment in technology, for understanding how a school's infrastructure affects its ability to provide educational services, it is also valuable to measure investment from non-financial data, even if these measures are expressed in terms of dollars. An estimate of a school's "overall technology investment" was constructed by combining data on recent expenditures with information provided by the technology coordinator on the installed hardware base, the school's software inventory, and measures of the amount of effort (rather than dollars) that currently goes into supporting teachers' use of technology.

Overall investment in computer technology hardware was based upon the number of computers, peripherals, and networking resources currently in use. Overall investment in software was based upon the number of computers installed with (or having access to) each of 20 different types of software. (See question B11 in Appendix.) Overall investment in technology support was based upon the weekly time spent by various persons on seven types of training, coordination, and user support activities. (See questions A3 - A4 in Appendix.)

By knowing (a) how much money was spent in a given category (e.g., hardware) during the past two years; (b) the total installed base at the school as of Spring, 1998; and (c) the proportion of the current installed base that was obtained during the most recent two years (from questions B5h for hardware and B13 for software), it was possible to estimate each school's investment in technology over a longer period of time. Across all schools, the average spent for each computer obtained during the past two years was $1,460, and the average spent on peripherals, including networking, was $161 per computer. By applying those amounts to the computers in every school's inventory at the time of the 1998 survey, the overall hardware investment for each school was estimated. Similarly, the average spent in the past two years per software unit was $18, and that amount was multiplied by the total software inventory to get an estimate of overall software investment. For measuring support investment over a longer period, we used information about average salaries of technology coordinators. From that data, we calculated the average per hour support cost as $18, which, when multiplied by five times the total hours spent by all persons on support over the past year, gives us an estimate for the 5-year period. Finally, each of these estimates (hardware, software, and support) was divided by the number of students to calculate the per student estimates for technology investment within each school.

These overall estimates, based on extrapolations from non-fiscal measures to monetary ones and from data on brief recent intervals to a more extended one represents our best estimate of the institutionalized level of investment into technology found in K-12 educational settings.
Figure 3 shows the one-year spending on the left and the overall technology investment on the right. An estimated total of $488 per student was spent overall for technology, and the proportions were not significantly different than the one-year expenditures. In general the overall technology investments were about 4 times that of the Fiscal Year 1998 expenditures, which suggests that the annual expenditure rate generally rose in the five-year period between 1994 and 1998.

FIGURE 3: AVERAGE PER-STUDENT TECHNOLOGY EXPENDITURES FOR FY98 VERSUS OVERALL TECHNOLOGY INVESTMENT OVER FIVE YEARS



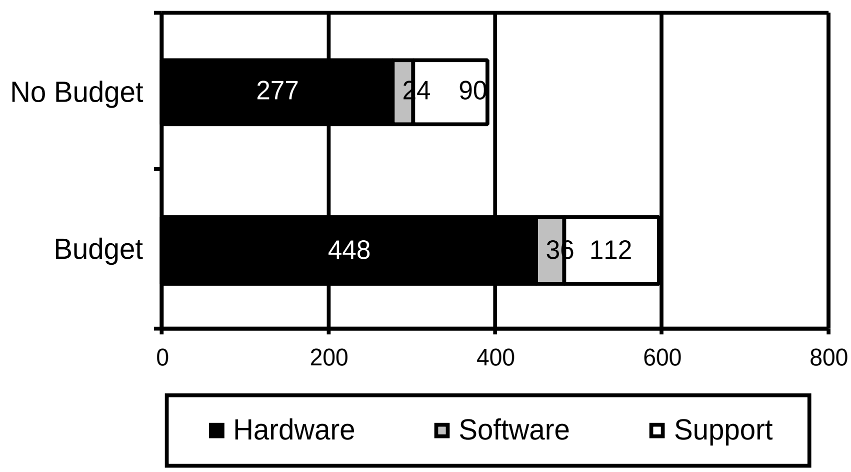
What Predicts Higher Spending for Technology?

Budgetary Autonomy.

In the United States some districts impose much greater control over school decisions than others. According to the technology coordinators, on average 46% of the funds for school technology (including hardware, software, and support) were from the district budgets and 54% were spent out of the school budgets. It is notable that districts are more likely to be the source of funding for hardware, whereas schools were more likely to be the source of funds for software and support services.

Some schools do not have a technology budget for which they have sole discretionary authority. In fact, a majority (54%) of the principals said they did not have their own budget for technology over which they had discretionary authority. The percent of schools with their own budget was essentially the same across all three levels of schooling, from elementary to high school. Figure 4 shows that having a technology budget is associated with considerably higher technology spending by the school. The comparison shown is for 5-year expenditures for each of the three categories of spending. The Figure shows that over the 5-year period, an average of $600 per student was spent by schools with their own budget, but only about $400 per student for those lacking one. One might expect this difference to be largely due to high schools having both greater budgetary autonomy and spending more on technology than do elementary schools. However, neither high schools nor middle schools are more likely to have their own budgets for technology. So, other factors such as school site-based management might account for a school having its own technology budget. Future research should explore the relative importance of such factors.

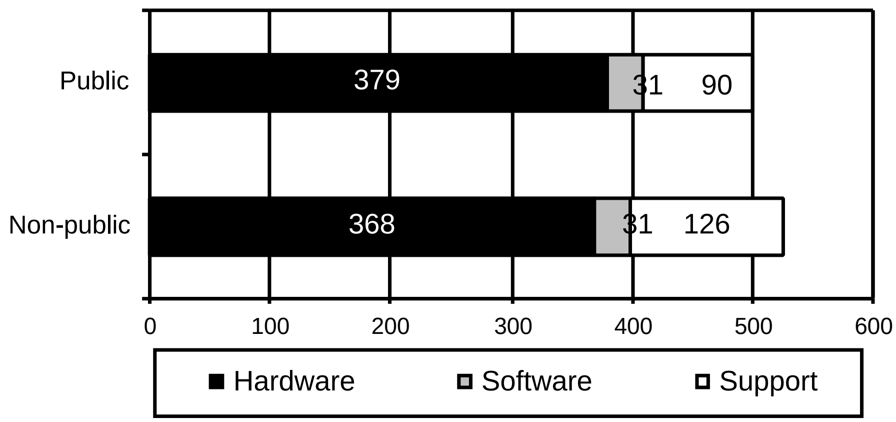
FIGURE 4: FIVE-YEAR PER-STUDENT TECHNOLOGY INVESTMENTS
BY WHETHER OR NOT THE SCHOOL HAS ITS OWN TECHNOLOGY BUDGET



Public Control

Most research on technology in American schools has been done on public schools, so less is known about non-public (private) schools. One might expect more technology spending in public schools because of large technology-oriented funding programs at both the federal and the state levels. On the other hand, non-public schools tend to have much smaller enrollments, which makes higher per-capita spending more feasible. Figure 5 compares these two types of schools in terms of 5-year investments. The Figure shows that the average difference in technology investment between public and non-public schools is small and not significant. Non-public schools were somewhat more likely to invest in technology support, but the difference could have resulted from sampling error.

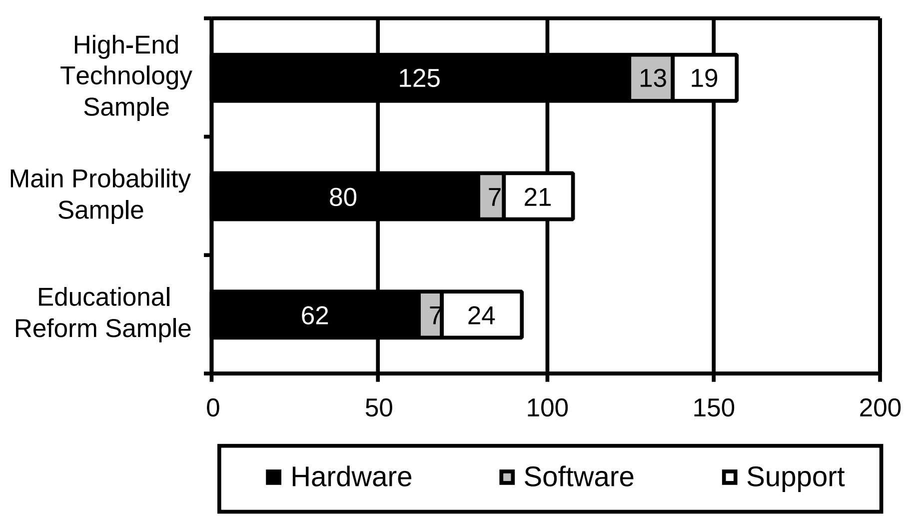
FIGURE 5: FIVE-YEAR TECHNOLOGY INVESTMENTS (PER STUDENT)
FOR PUBLIC SCHOOLS AND NON-PUBLIC SCHOOLS



Participation in School Reform

As discussed earlier in this paper (where the study's samples were described) the study included two non-representative, purposive samples: (1) schools known to have a high density of computer technology and (2) schools known to participate in a program of instructional reform. While some of the reform programs had a technology component, most of them did not emphasize technology. Figure 6 shows the average school technology investments for these two groups, comparing them to the main, representative sample. The "educational reform" schools were slightly lower in technology spending than the main probability sample schools, but they are not significantly different. However, the "high-end technology" schools invested considerably more (by about 50%) than the representative probability sample, which in a sense validates their selection. Nevertheless, the higher investments in high-end technology schools were confined to hardware and software; they did not extend to providing a higher level of support services.

FIGURE 6: FISCAL YEAR 1998 TECHNOLOGY INVESTMENTS (PER STUDENT)
COMPARING THREE DIFFERENT TLC SAMPLES



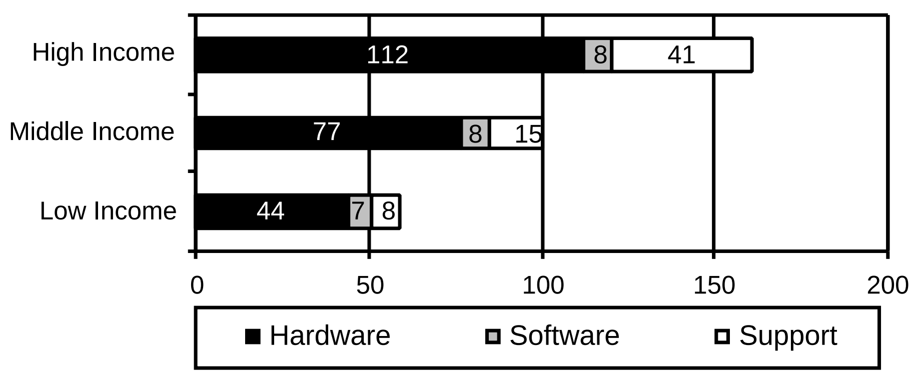
The Digital Spending Divide

Substantial differences exist among families in their own private investments in educational technology. Because schools also differ in the socio-economic distribution of their students, it is important to know the extent that schools reinforce private socio-economic inequalities in terms of access to computer technology, or the extent that they counteract such inequalities.

Community Income Differences

Using a measure of the average household income within a school's zip-code, it was possible to compare schools serving low-income communities with those serving higher income families in terms of their investments and expenditures in computer technology. The comparisons were made across three categories, where 'low income" comprised the lowest 10% of the schools, 'high income' included the top 40% of the schools with respect to community income, and 'middle income' the remaining 40%. As shown in Figure 7 the highest 40% of the schools spent well over twice as much per capita as the lowest 10%. This is significant, because big differences in computer density do not exist in schools across these income groups. (See Anderson and Ronnqvist, 1999.) Thus, the recent pattern of higher spending among the wealthier schools suggests a possible widening of infrastructure disparities.

FIGURE 7: SCHOOL TECHNOLOGY EXPENDITURES (PER STUDENT) FOR FISCAL YEAR 1998 BY COMMUNITY INCOME LEVEL, TLC 1998

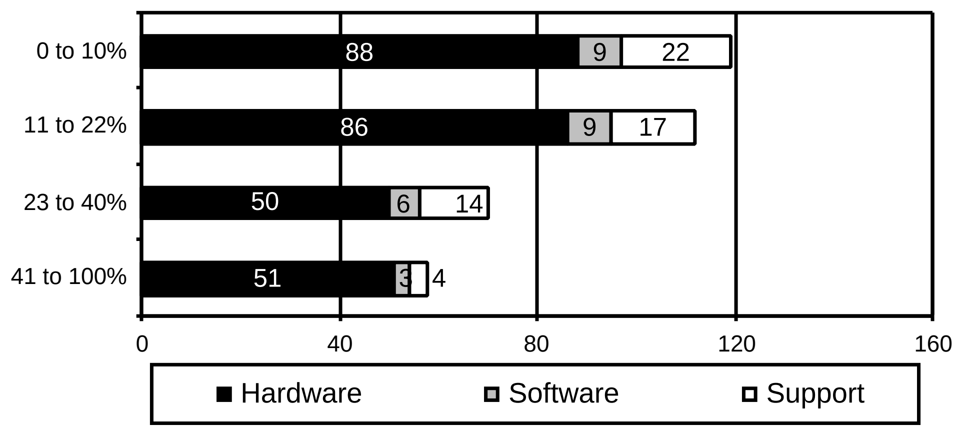


Another cause for concern about schools in very low-income communities is that they are spending much less than other schools on technology support. Figure 7 shows that the lowest income schools spent an average of only $8 per student for technology support, whereas those in higher income communities spent $41 or 5.2 times as much. This implies that technology implementations are likely to be much less effective in schools serving students in poorer communities.

Title I Eligibility Differences

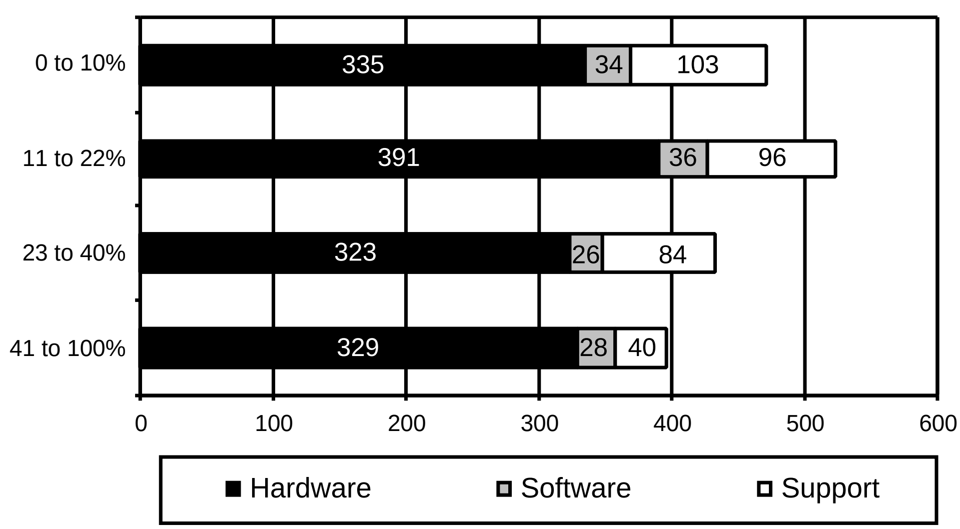
A somewhat similar pattern was found by comparing schools that differ by the percent of their students that were eligible for Title I support. (Title I eligibility is based upon family poverty guidelines and corresponds with eligibility of children for free or reduced lunch.) The schools were divided into four equal size groups on the basis of the percentage of students reported to be eligible for Title I funding. Figure 8 shows the per student expenditures for FY98 on hardware, software, and support for each of the four income levels as measured by eligibility. The results show that those schools with the fewest eligible (highest income quartile) spent twice as much as the quartile of schools with the most eligible (lowest income quartile). Note also that this quartile with the most eligible for Title I funding were spending on the average only $4 per student on support, which was less than one fifth of that spent on support by the schools with the fewest students below poverty. As noted above this poses serious implications for the capacity of lower income schools to utilize technology successfully.

FIGURE 8: SCHOOL TECHNOLOGY EXPENDITURES (PER STUDENT) FOR FISCAL YEAR BY PERCENT ELIGIBLE FOR TITLE I, TLC 1998



If we look at investments by attending to the installed base of hardware and software rather than expenditures over the last year, a different pattern emerges. Specifically, the differences in overall technology spending across the schools differing in their Title I eligibility (income levels) were not large. (See Figure 9.) In fact, the schools with the fewest Title I-eligible students (highest income) differed from the schools serving the poorest student populations only in terms of their greater expenditure on teacher support services—not in terms of hardware or software.

FIGURE 9: FIVE-YEAR INVESTMENT ON SCHOOL TECHNOLOGY (PER STUDENT) BY PERCENT ELIGIBLE FOR TITLE I, TLC 1998



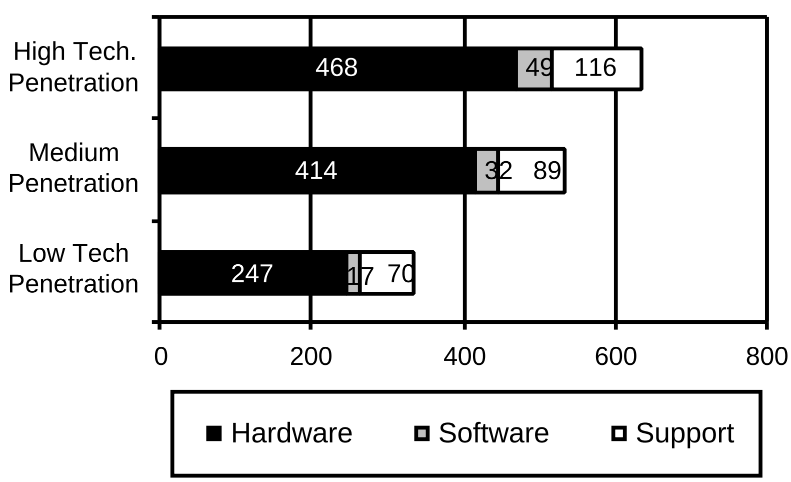
Overall the pattern is consistent with the conclusion that the installed base of computers does not differ significantly by Title I groups (Anderson and Ronnkvist, 1999). During the mid-1990s, Title I and other compensatory funding programs tended to equalize the technology resource base or infrastructure across richer and poorer schools. However, more recent spending patterns (the one-year expenditures shown above in Figure 8) suggest a renewal of past patterns of socio-economic differences in technology spending. Perhaps the high demand for leading-edge technologies such as high-speed Internet access and multimedia computer components (Anderson and Ronnkvist, 1999) is producing this new digital divide. These data suggest that the poorer schools have not had nearly as much capacity to invest in the newer technologies as have the higher income schools.

The Relationship between Technology Spending and Teaching Practices

Now we turn to the question of whether or not the volume and type of technology spending is associated with the number of teachers in the school who use technology and how much they do so.

First we will examine the "penetration" of technology into the teaching practices of each school's teachers. To measure technology penetration, we used a set of items from our technology coordinators' survey that asked about the proportion of teachers at the school who were employing computers in various aspects of their teaching. Technology coordinators were asked what proportion of the teachers did each of the following: (1) experiment with new teaching methods involving computers, (2) use computers for their own professional tasks, (3) sometimes have students use computers to do curricular assignments, (4) become involved in planning or implementing Internet-based activities, and (5) seek out technology coordinators for advice about integrating technology and curriculum. By accumulating the answers to these questions, we produced a measure of technology penetration. Figure 10 gives the results from calculating the per-student overall technology investment for each of three levels of technology penetration at the school level. The figure reveals a strong, linear relationship. The total spending for high-penetration schools is almost twice that of low-penetration schools.

FIGURE 10: FIVE-YEAR SCHOOL TECHNOLOGY INVESTMENT (PER STUDENT) BY LEVEL OF TECHNOLOGY PENETRATION, TLC 1998



Teacher-Level Data on School Technology Investments and Teachers' Computer Use: Procedures

Up to this point in the paper, our presentation has been based on school-level data—principally, information from the school technology coordinator in each of the schools in the TLC national probability sample. To explore more detailed relationships between school technology investment and teacher computer activity, we analyzed data from the teacher surveys in the TLC study. Also, in this section, we expand the base of school-level information from the national probability sample to include the purposive sample of reform-involved and high-end technology schools as well. (See above, p. 4.) For each of the 4,083 teachers in the TLC database, we correlated various aspects of that teacher's use of computers with the technology investment characteristics of the school in which he or she works.

In particular, we examined whether teachers whose schools invest more heavily in computer technology, or who do so by emphasizing different elements (i.e., hardware, software, or support), use computers in a different way than other teachers do. The aspects of teacher computer use which we examine include (a) how frequently they have students use computers and different types of computer software during class time; (b) how knowledgeable they are about computers and how much they use computers themselves for professional functions; (c) how much more often they report having had training dealing with computer use; (d) how much more often they report engaging their colleagues in informal conversation dealing with computer-related teaching issues; (e) how much they have increased their use of computers over the past five years; (f) whether they see computers as partly responsible for recent changes in their teaching that they have introduced into their practice; and (g) whether they see computers as having had a role in changes in their curriculum priorities and their teaching goals.

Each possible outcome variable is described here only in general terms. For details on the construction and interpretation of each variable, see the various other reports from the study on the TLC website.

After examining a number of measures of school technology expenditure (1-year dollar-based estimates) and technology investment (5-year, inventory and support-effort measures), we found that the relationships between teacher practice and school technology investment were clearest for the five-year investment measures. Our presentation focuses on four such measures:

- The total per-capita five-year technology investment (TOTAL)
- The per-capita five-year investment in hardware and infrastructure (as reflected in inventory) (HARDWARE)
- The per-capita five-year investment in software (as reflected in inventory) (SOFTWARE)
- The relative five-year investment in technology support and training; that is, the proportion of the total investment that went for support and training (ALLOCATION TO SUPPORT)

For this analysis, separate correlations between teacher practice outcome variables and school technology investment measures were calculated for five subsets of teachers: (1) secondary (i.e., middle- and high school) mathematics teachers; (2) secondary English teachers; (3) secondary science teachers; (4) secondary social studies teachers; and (5) elementary (grades 4-6) teachers. Secondary teachers were defined in terms of the principal subject that they taught. Teachers whose principal subject was in another field are omitted from this analysis.

Technology Investment and Frequency of Teachers Assigning Computer Work During Class

Table 2 shows the relationship between the four different measures of technology investments and one specific outcome—how frequently the teacher assigned computer work to one specific class of students.

The relationships are nearly all positive but are stronger for mathematics teachers than for other teachers and weaker for social studies teachers than for others. For four of the five groups of teachers, the strongest correlation with frequency of assigning computer work was the total school-level software inventory; only for social studies teachers was this correlation negligible. Also, the correlations were all at or above .10 (for all except social studies teachers) between frequency of assigning computer work and the proportion of all technology investment attributed to support and training effort.

TABLE 2: CORRELATIONS BETWEEN SCHOOL TECHNOLOGY INVESTMENTS AND FREQUENCY OF TEACHER ASSIGNING COMPUTER WORK DURING CLASS, BY SUBJECT AND LEVEL OF TEACHER

	Estimated Technology Investment over 5-years			Allocation Among Types of Investment
	TOTAL Investment	HARDWARE (inventory)	SOFTWARE (inventory x % of comps. runs on)	Support & Training time relative to hardware/software inventory
Secondary English Teachers	.13	.14	.20	.10
Secondary Mathematics Teachers	.22	.20	.38	.33
Secondary Science Teachers	.06	.03	.16	.14
Secondary Social Studies Teachers	.05	.07	.01	-.04
Elementary Teachers	.14	.12	.22	.16
Average correlation across the five types of teachers	.12	.11	.19	.14
Summary measure: (.10 ≤ r ≤ .14) x 1 + (.15 ≤ r ≤ .24) x 2 + (.25 ≤ r) x 3	4	4	9	7

Table 2 shows two ways of summarizing the strength of the relationship between the investment variables and the teacher practice variable—the mean correlation across the five teacher groups; and a simple, weighted count of the number of small, moderate, and large correlation coefficients, using cutoff points of .10, .15, and .25 to define the minimum criterion for regarding the correlation as small, moderate, or large, respectively. Subsequent analyses used this second summary measure in order to focus on the consistency of finding relationships between investment variables and teacher practices; in other words, the more frequently that the same relationship was replicated across the five teacher groups, the more likely the association was regarded as worth attending to.

Teacher-Directed Student Use of Computers and School Technology Investment

Table 3 shows that the findings for overall frequency of student computer use are paralleled for a range of measures of teachers' use of computers as resources for student work during class, including the frequency that the teacher assigned students to use specific types of software such as word processing programs or Web browsers. For all nine outcome measures in Table 3, frequency of student software use was more a function of the school's software investment than it was a function of hardware inventory or training and support effort. In addition, specific types of software had unique patterns. For example, frequent use of e-mail was more dependent upon hardware investment than on support (schools need many student stations but e-mail software is easy to use), while the opposite was true for spreadsheet and database programs (i.e., without being trained in the use of such programs, teachers are not likely to assign students to use them either).

TABLE 3: TEACHER-DIRECTED STUDENT COMPUTER USE AND SCHOOL TECHNOLOGY INVESTMENT: NUMBER OF INDICATORS OF A POSITIVE ASSOCIATION*

	Estimated Technology Investment over 5-years			Allocation Among Types of Investment
Measure of Teacher-Directed Student Computer Use	TOTAL Investment	HARDWARE (inventory)	SOFTWARE (inventory x % of comps. runs on)	Support & Training time relative to hardware/ software inventory
Frequency of assigning computer work during class	4	4	9	7
Breadth of software students use frequently	6	5	10	7
Frequent use of word processing	7	5	7	4
Frequent use of WWW browser	6	6	9	9
Frequent use of CD-ROM reference	4	2	5	3
Frequent use of presentation software	2	2	6	2
Frequent use of student multimedia authoring	2	2	3	0
Frequent use of spreadsheets/database software	2	1	4	4
Frequent use of e-mail	5	5	5	2
Total across all measures of teacher-directed student computer use	38	32	58	38
Total for…English Teachers	12	12	17	6
Mathematics Teachers	12	9	14	12
Science Teachers	1	1	9	8
Social Studies Teachers	1	1	1	1
Elementary Teachers	12	9	17	11

* Weighted number of correlations across five groups of teachers, grouped by subject taught. For each correlation, the following weights are applied: 1 for $.10 \le r < .15$; 2 for $.15 \le r < .25$; 3 for $r \ge .25$. The last five rows provide cumulative total weights for teachers of a given subject across each of the indicators above.

Across the nine frequency-of-use variables, English teachers, math teachers, and elementary teachers are all about equally likely to be affected by school technology investments. For each of those groups, software investment matters most. For English teachers, who are more apt to assign students to do word processing than in other classes, hardware investment comes second. Science teachers are much less affected by hardware investment than they are by either software or support and training investment. Social studies teachers appear not to be affected by school technology investments at all—for that group, only one correlation with each investment variable met even the minimum standard for a small relationship (r=.10).

Teacher Professional Involvement with Computers and School Technology Investment

It is not simply frequent software use that is associated with school technology investment, but a broad range of ways that teachers are connected to computer use in their teaching practice. Table 4 provides results similar to those presented above for four aspects of a teacher's computer-use practice: whether they had participated in formal staff development workshops dealing with various computer topics; how frequently they had informal discussions with other teachers about using computers; a composite measure of the teacher's knowledge about computers and their use of a variety of professional software applications; and how much their use of computers in teaching had increased over the previous five years. Again, across these disparate dimensions of computer use, a school's software inventory (variety of software multiplied by the proportion of computers on which that software is installed) was more commonly correlated with teacher computer use than with either the school's hardware investment or the proportion of school technology investment going towards teacher support or training.

TABLE 4: PROFESSIONAL USE OF COMPUTERS CORRELATED WITH SCHOOL TECHNOLOGY INVESTMENT: NUMBER OF INDICATORS OF A POSITIVE ASSOCIATION*

	Estimated Technology Investment over 5-years			Allocation Among Types of Investment
Measure of Teacher Involvement with Computers	TOTAL Investment	HARDWARE (inventory)	SOFTWARE (inventory x % of comps. runs on)	Support & Training time relative to hardware/ software inventory
Participation in staff development in past year dealing with computer topics	4	4	6	5
Frequency of informal discussions with other teachers about computers	4	2	4	2
Computer knowledge and professional use (scale)	3	3	6	3
Increased use of computers in teaching over past 5 years, both professionally and with students	3	4	5	3
Total Across All Measures of Teacher Involvement with Computers	14	13	21	13
Total for…English Teachers	1	2	4	1
Mathematics Teachers	5	4	4	1
Science Teachers	0	0	1	2
Social Studies Teachers	4	4	4	2
Elementary Teachers	4	3	8	7

* See footnote to Table 3.

Among the five groups of teachers studied, elementary teachers' involvement in computers was more consistently associated with school technology investment practices than any of the secondary academic subject-matter teachers—particularly in terms of software investment and support and training activities. However, in contrast to the finding that the frequency which social studies teachers used software was unrelated to their school's technology investment practices, social studies teachers appear to be affected by school technology investments as much as other secondary teachers in terms of how much they participate in computer-related staff development. One possibility consistent with those results is that in schools with substantial technology investment social studies teachers participate in learning how to use computers as much as other teachers, but they don't actually tend to use what they learn. Whether that lesser use is a function of having less access to computers or that they were less likely to understand how to apply computer skills to their existing pedagogy and curricular goals has not been investigated.

Teachers' Perception of Computers' Effects and School Technology Investment

The final set of comparisons made between teachers working at schools with different patterns of technology investment was in terms of teachers' perceptions of the effect of computers on their own teaching practice. On the pages of the survey which asked teachers to discuss changes during the past three years in their teaching practices, four questions asked them to reflect on the role that computers played in the changes that they reported. One question asked about changes in the types of assignments they gave and other teaching strategies that they used. A second question asked about changes in their beliefs about curriculum priorities; a third asked about changes in teaching goals; and a fourth question asked how important computers were in "all of the ways that you have changed your teaching practice over the past three years."

Generally speaking, teachers in schools with different patterns of technology investment did not give very different answers to these questions, at least compared to how they answered questions about software use, computer training, and professional use of computers. (See Table 5.) However, again it was the richness of the school's software inventory that most distinguished teachers in terms of their judgment about whether computers had made a difference in their teaching. Hardware inventory was a close second and the proportion of total investment going towards teacher support and training as a distant third, with even some instances of negative correlations being observed. Across the five groups of teachers, elementary teachers' perceptions appear to have been most affected by their school's investment practices and English teachers the least affected.

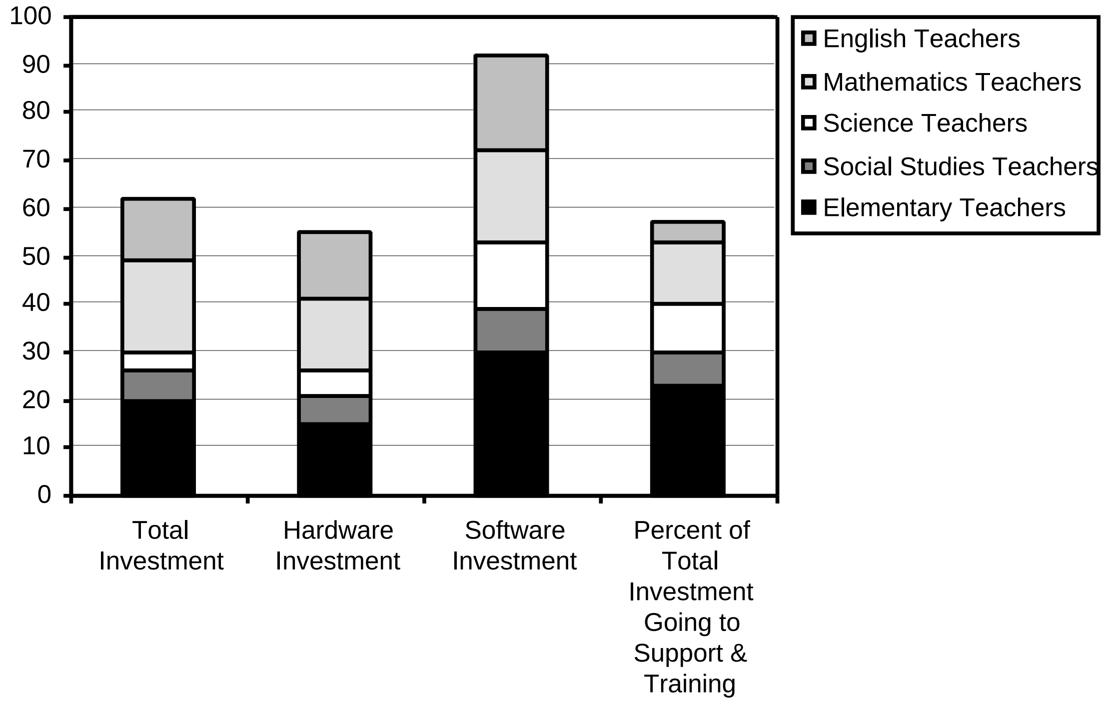
TABLE 5: TEACHER PERCEPTIONS OF EFFECTS OF COMPUTERS ON TEACHING PRACTICE BY SCHOOL TECHNOLOGY INVESTMENT: NUMBER OF INDICATORS OF A POSITIVE ASSOCIATION*

	Estimated Technology Investment over 5-years			Allocation Among Types of Investment
Measure of Teacher Perception of Computer Effects	TOTAL Investment	HARDWARE (inventory)	SOFTWARE (inventory x % of comps. runs on)	Support & Training time relative to hardware/ software inventory
Ascribes increased use of constructivist teaching strategies to computers in teaching	3	2	5	4
Believes computers have affected beliefs about curriculum priorities	3	3	2	(2)
Believes computers have affected teaching goals	2	1	2	(1)
Ascribes all types of recent changes in own teaching practice to experiences with computers	2	4	4	4
Total Across All Measures of Teacher Perception of Computer Effects on Teaching Practice	10	10	13	5
Total for…English Teachers	0	0	(1)	(3)
Mathematics Teachers	2	2	1	0
Science Teachers	3	4	4	0
Social Studies Teachers	1	1	4	4
Elementary Teachers	4	3	5	5

( ) More negative correlations than positive ones.
* See footnote to Table 3.

Finally, Figure 11 summarizes our findings at the teacher level, by subject-matter of teachers. Across all 17 outcome variables examined in Tables 2-4, software provided 50% more notable correlations (weighted by the classification of correlation magnitudes discussed above on page 15) as any of the other measures of school-level technology investment. Each of the other three measures—total 5-year investment, hardware inventory, and the percent of total investment going to support and training—were roughly comparable in how strongly they related to teacher practices and perceptions of the role of computers in their teaching. Among the five groups of teachers, elementary teachers were most affected by school technology investment patterns and science and social studies teachers the least affected, at least as measured through these statistics.

FIGURE 11: SCHOOL TECHNOLOGY INVESTMENT AND NUMBER OF NOTABLE CORRELATIONS WITH TEACHER-LEVEL OUTCOMES, BY SUBJECT-TAUGHT



CONCLUSIONS

While American schools are spending billions of dollars annually on technology, this amounted to a mere $133 per student in 1998. Even three years later it is probably no more than $175 per student. Compared to information-intensive businesses, this is a drop in the bucket, and until spending levels rise substantially, the impact on students is likely to be severely constrained.

This report documents the relative neglect of spending for software and technology support. Without both greater attention to improving the quality of support for teachers and their instructional applications of new technology, schools will lack the capacity to take advantage of technology's potential for improving instruction. The lack of investment in software in particular seems striking given that teacher-directed student use of computers during class time, teacher professional involvement with computers, and their perceptions of the effects computers have had on their teaching practice were all much more a function of their school's investment in software than in their school's hardware installed base.

In this report we also document a major digital divide in technology investment, with poorer schools spending far less on technology than richer ones. Furthermore, the digital divide was widest in one of the two most critical areas, that of technology support. In other words, schools with large concentrations of lower income students spend a smaller portion of their technology funds on teacher training and support than do schools serving wealthier students. This finding suggests that not only does this lower the capacity of poorer schools to utilize the technology that they now have, but they are less likely to be able to evaluate and adapt to new technologies as they emerge in the future.

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APPENDIX

Survey Questions Related to Technology Investment
from the Technology Coordinator Questionnaire

A3. Roughly how many hours per week, on the average, do you actually spend providing technology, training, coordination, and user support in each of the following ways? *Think about last week in particular; then adjust if it was different than usual. If you also work at other schools, count only the hours spent for* ***this*** *school.*

# of hours

a. Supervising and assisting computer use by classes **of other teachers**.......................... ________

b. Supporting or training individual teachers in their use of computers including impromptu help.. ________

c. Installing, troubleshooting, and maintaining equipment, networks, operating systems, and software .... ________

d. Planning and running staff development workshops or in-services on technology ...... ________

e. Writing lesson plans and units with other teachers that integrate computer activities with curriculum .... ________

f. Selecting and acquiring computer-related hardware, software, and support materials for the school.. ________

g. Other technology coordination and support (please describe): .... ________

Describe: ____

A4. For each person, other than yourself, who regularly provides technology support for teachers at your school, please indicate their position and the approximate number of hours each provides this support per week. *Use a separate line for each person.*

PERSON #	Teacher	Administrator	District/ Diocese person	Aide	Other school professional	Others outside school	Volunteer	Approx. # of hours per week
1.	❑	❑	❑	❑	❑	❑	❑	______
2.	❑	❑	❑	❑	❑	❑	❑	______
3.	❑	❑	❑	❑	❑	❑	❑	______
4.	❑	❑	❑	❑	❑	❑	❑	______
5.	❑	❑	❑	❑	❑	❑	❑	______
	1	*2*	*3*	*4*	*5*	*6*	*7*	

A. If more than five persons provide this type of technology support, how many additional do so?.. ________

B. How many more total hours per week do these people provide support?........... ________

A5. *Since September*, on how many occasions have teachers in your school received formal computer technology training, direct tutoring, or support? Also, please roughly estimate the average number of teachers served per occasion. *Include yourself in those situations where you are a learner rather than a trainer.*

	# of Occasions	Average # of Teachers Served
a. One-on-one or small group tutoring or training sessions about technology....................................	________________	________________
b. School-presented technology in-service workshops	________________	________________
c. District/Diocese presented technology in-service workshops	________________	________________
d. State or regionally sponsored workshops or technology conferences...	________________	________________
e. Commercially presented workshops or courses on technology..	________________	________________
f. College or university courses on technology........	________________	________________
g. Other (please describe): ____________________	________________	________________

PART B: NATURE AND COST OF THE SCHOOL'S INFORMATION TECHNOLOGY INFRASTRUCTURE

B1. **How many computers at your school are used primarily by administrators, support staff, and cl** ....

______

Don't Know.................................. ❑

B2. **How many of your computers are used primarily as file-servers, print-servers, e-mail-servers, student or teacher use?** ....

______

None……..(GO TO B3)……………. ❑

A. **Which of the following types of servers do you have?** ✓ *ALL that apply.*

1. A file-server for an integrated learning system (ILS) .... ❑
2. A file server for a local area network that is not an ILS .... ❑
3. An electronic-mail server .... ❑
4. A print server.. ❑
5. An Internet server (e.g., Web site server).. ❑

B3. **This question is an inventory of your school's computers and where they are. We would like you to count the number of computers used by students or teachers by type of computer for each of three locations: "labs", "classrooms", and "other places".**

You may use one row to inventory all the computers in that type of room (e.g., labs) or combine several rooms on one row, or use each row for a different room. Your choice.

Include both desktop and laptop computers, but only those used by students and teachers to do instructional work. DO NOT include either administrative computers or servers identified in the previous question.

	WINDOWS & DOS PCs			MAC OS		APPLE II SERIES	OTHER	TOTAL
	Pentiums	**386 or 486**	**286 and earlier**	**Power Macs and similar**	**Older Macs (68xxx)**			
COMPUTER LABS, MEDIA CENTERS								
CLASSROOMS								
OTHER PLACES E.G. TEACHERS' ROOMS, PODS, ROVING LAPTOPS, ETC.								
TOTAL								

B4. Please estimate how many rooms in your school are used for any instruction .... ______
If none, write "0".

Of these rooms used for any instruction, how many have:

a. 16 or more computers .... ______

b. Exactly 1 computer .... ______

c. no computers at all .... ______

d. at least one computer connected to a multi-room network (LAN) at the school .... ______

e. at least one computer connected to the Internet through a LAN (high-speed connection)... ______

B5. How many computers at your school: *If none, write "0".*

a. are laptop or notebook computers.. ______

b. have direct access to a printer whenever used .... ______

c. have an internal or directly attached CD-ROM drive .... ______

d. have an internal or directly attached modem .... ______

e. are attached to a Local Area Network (LAN) for sharing files, etc.) .... ______

f. can have simultaneous Internet access.. ______

g. were acquired either this school year or last (July, 1996 or later) .... ______

h. were acquired before July, 1996 .... ______

B6. Do you have a video production studio that students can use? ❑ Yes ❑ No (GO TO B7)

A. If yes, what computer-related equipment does your video production studio include?

____

____

B7. Not counting equipment included in a video production studio, approximately how many of the following computer peripheral units or other devices are present at your school?
If none, write "0".

	# of units
a. Computer printers	______
b. Computer LCD panel or projection devices	______
c. Laserdisc players that can be computer-controlled (Level 3)	______
d. Computer scanners for graphics	______
e. Optical drives, disk arrays, high-end disk drives, CD-ROM towers	______
f. Camcorders	______
g. Digital cameras	______
h. Other computer peripherals generally costing $500 or more each	______

B8. In order to connect your school's computers into a local area network (LAN) or to attach a local area network to the Internet, has it been necessary during the past two years to install any new conduits or equipment within the school or to build or remodel any rooms for network equipment including electrical or air conditioning upgrades?

❑ Yes

❑ No (GO TO B9)

❑ School has no LAN (GO TO B10)

A. Please describe by listing the items changed or remodeled for LAN installation since July, 1996.

1. ______________________________

2. ______________________________

3. ______________________________

4. ______________________________

B9. How are your school's computers or your local area network connected to the Internet?
Respond in two columns--once for your school's instructional computers, and once for computers only used for administrative purposes. ✓ ALL that apply for each column.

	Instructional Computers	Computers used only for Administration
a. None—no Internet connection or modem	❑	❑
b. Modem	❑	❑
c. ISDN	❑	❑
d. 56K bandwidth line(s)	❑	❑
e. T1 bandwidth line or higher..................................	❑	❑
f. Other (please describe): ____________________	❑	❑
	1	*2*

B11. What fraction of the computers in your school have the following software accessible for teachers or students to use?

✓ *the closest choice for each.*

	None	Very few	1/4	1/2	3/4	Almost all	All
a. Word processing	❑	❑	❑	❑	❑	❑	❑
b. Spreadsheet	❑	❑	❑	❑	❑	❑	❑
c. Database	❑	❑	❑	❑	❑	❑	❑
d. Drawing or painting software	❑	❑	❑	❑	❑	❑	❑
e. Desktop publishing, presentation software	❑	❑	❑	❑	❑	❑	❑
f. Image-editing software (e.g., PhotoShop)	❑	❑	❑	❑	❑	❑	❑
g. Multimedia development (e.g., Hyperstudio)	❑	❑	❑	❑	❑	❑	❑
h. Reference information on CD-ROM	❑	❑	❑	❑	❑	❑	❑
i. Interactive laserdisc software	❑	❑	❑	❑	❑	❑	❑
j. Internet (e.g., Netscape, e-mail software)	❑	❑	❑	❑	❑	❑	❑
k. Web development tools	❑	❑	❑	❑	❑	❑	❑
l. Programming languages	❑	❑	❑	❑	❑	❑	❑
m. Math-specific programs	❑	❑	❑	❑	❑	❑	❑
n. Science-specific programs	❑	❑	❑	❑	❑	❑	❑
o. English-specific programs	❑	❑	❑	❑	❑	❑	❑
p. Social studies-specific programs	❑	❑	❑	❑	❑	❑	❑
q. Foreign language-specific programs	❑	❑	❑	❑	❑	❑	❑
r. Typing tutors	❑	❑	❑	❑	❑	❑	❑
s. Business education-specific programs	❑	❑	❑	❑	❑	❑	❑
t. CAD-CAM, industrial arts programs	❑	❑	❑	❑	❑	❑	❑
	1	*2*	*3*	*4*	*5*	*6*	*7*

B13. Approximately what percentage of the software in use at your school has been acquired in the last two years (since July, 1996)? ✓ *only one.*

1. None ❑
2. 10% ❑
3. 20% ❑
4. 30% ❑
5. 40% ❑
6. 50% ❑
7. 60% ❑
8. 70%+ ❑

B14. You have been describing your school's investments in computer-related hardware, software, and teacher support for technology. We would now like to know what those investments have cost your school in financial terms in the past two years. *Exact figures are not needed, just give rough estimates. If you do not know at all, write "DK."***.** *If nothing was spent on a given aspect, please enter a "0".*

EXPENDITURES IN PAST TWO YEARS (JULY '96 THROUGH JUNE '98)

	School Funds	District Funds
a. Instructional computers used by teachers or students (including any ILSs and servers)	$ __________________	$ __________________
b. Peripherals (printers, computer projection devices, graphics scanners, CD-ROMS, digital cameras, etc.)......	$ __________________	$ __________________
c. Video production facilities................	$ __________________	$ __________________
d. Computer furniture and security equipment...	$ __________________	$ __________________
e. Local Area Network (LAN) connections and retrofitting	$ __________________	$ __________________
f. Internet and other outside data communication lines	$ __________________	$ __________________
g. Computer maintenance contracts and repair services	$ __________________	$ __________________
COMPUTER SOFTWARE		
h. Individual software purchases, lab-packs, and one-time upgrades...........	$ __________________	$ __________________
i. Site licenses and annual contract fees..	$ __________________	$ __________________
SUPPORT AND TRAINING FOR TEACHERS		
j. Portion of salary of Technology and/or Network Coordinator	$ __________________	$ __________________
k. Portion of salaries of others providing training	$ __________________	$ __________________
l. Release time, participant costs, and other expenses of training recipients .	$ __________________	$ __________________
m. Other expenses enabling training and support	$ __________________	$ __________________