A Shrinking "Digital Divide"? The Provision of Classroom Computers across Urban School Systems*

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Objective. To determine the extent of the urban school "digital divide"—the varying provision of computer technology to students of different races and classes—and whether it has changed in the 1990s. *Methods*. Ordinary least squares and logit regression analysis is conducted on the 1995 Council of Urban Boards of Education survey, encompassing 72 urban school districts. *Results*. Districts with a higher percentage of African American students provided fewer computers per student, whereas community educational level, family income, and Latino enrollment had no effect. On the other hand, districts with more African American students reported recent decreases in the student-to-computer ratio, and comparisons with recent research suggest that the magnitude of this digital divide has decreased. *Conclusions*. Urban school districts appear to be addressing the digital divide, although inequalities in computer access remain.

The role of technology in schools and classrooms is rapidly becoming one of the most pressing and widely discussed issues in contemporary education policy (Alspaugh, 1999; NTIA, 1999; Owens and Waxman, 1996; Riel, 1992; Rosen and Weil, 1995; Thierer, 2000). There is nearly universal agreement that, when properly used, computers and technology hold immense promise to improve teaching and learning as well as shape workforce opportunities. Computer illiteracy has been dubbed the new illiteracy (Poole, 1996),[1] and this has fostered a strong desire to equip schools with the equipment and faculty necessary to produce technologically proficient students. A variety of studies have found positive effects associated with

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[1] Such equity concerns are not unique to technology policy but characterize the broader debate over how educational opportunity is distributed in the United States and the manner in which the nation finances and provides schooling (see Bartoli, 1995; Darling-Hammond, 1994, 1998; De Luna, 1998; Kozol, 1991).

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computer-aided or technology-aided instruction (Barron et al., 1999; Burnett, 1994; Christmann and Badgett, 1999; Fitzgerald and Werner, 1996).

On a less promising note, concerns about a "digital divide" between black and white and rich and poor have become a staple of the discussions about educational technology.[2] Some researchers express concerns that the cost and complexity of the new technologies may accentuate inequities that already beset American education. Cole and Griffin (1987), for example, have argued that although technology needs to be an integral part of a well-planned pedagogy for students, programs need to be designed so as to ensure equitable and substantial access. There is particular concern about the equity implications of educational technology in urban areas, where minorities and low-income populations already face serious educational disadvantages as they seek to enter the new economy.

Critics fear that poor school systems will not offer students the training required to develop computer literacy and that differential access to computer-equipped schools will produce technological winners and losers (Becker and Ravitz, 1998; Leigh, 1999; Owens and Waxman, 1996). Much of this debate tends to be rhetorical or to focus on the gaps between suburbia and urban areas, whereas little attention has been paid to the inequities that may exist among urban areas. This article therefore examines how equitably urban school districts, which have relatively large minority and low-income populations, provide students with classroom computers.

The question of interurban equity is particularly important because governmental and philanthropic efforts to provide technology to schools presume that most cities are disadvantaged and therefore offer support to districts in a relatively undifferentiated manner. In addition, because legislators represent geographic districts, there is a temptation for federal policymakers to sprinkle education technology dollars over a number of locales (Arnold, 1990). As of 1996, urban districts generally received most of their funding for technology initiatives from federal funds, so this "shotgun" approach may have hindered the federal government's ability to effectively address the cross-city digital divide (Walker, 1997).

Such an approach is apparent in the administration's fiscal year 2001 budget, which earmarked more than $900 million for educational technology. Less than half of that money was targeted for "low-income" districts, and even the targeted money would be distributed according to need-based formulas that would label almost all urban districts as eligible for some aid (Rosenthal, 2000a). Of the $10–12 billion in other technology-related fed-

[2] For a comprehensive discussion of the subject, see Irving (1999), which reported that persons with at least a college degree are more than 8 times as likely to have a computer, 10 times as likely to have Internet access at their jobs, and nearly 16 times more likely to have home Internet access than are persons without a college degree. This gap grew by 25 percent from 1997 to 1998. The gap is mirrored by an ethnic divide, as African American and Latino households were only 40 percent as likely to have home Internet access as white households.

eral education spending proposed for fiscal year 2001, most was intended to fund Title I grants or 21st Century Community Learning Centers that direct money to nearly every urban district (Rosenthal, 2000a).

Similarly, the administration's proposed digital divide initiative includes extensive federal tax incentives for private-sector activities that could be claimed by firms operating in nearly any urban district (Rosenthal, 2000b). In short, there is a strong tendency toward directing federal aid to a broad swath of urban districts, which could make the alleviation of an urban digital divide more difficult. On the other hand, if technological disparities do not exist or are not substantively significant, as has been suggested by some researchers (Rapp, 1999; Thierer, 2000), then current efforts to aid urban schools may produce an equitable distribution of such resources.

This article focuses on two central issues in the debate over the digital divide. First, what causes some urban districts to provide more access than others to classroom computers? In particular, the article considers the role played by the racial and ethnic composition, education, and income of the local population. The second question is whether the digital divide is growing or shrinking. Are some districts integrating computers into their classrooms more rapidly than others, and are those districts racially or economically distinctive? In light of the efforts made by governmental, philanthropic, and advocacy groups since the early 1990s, there is some reason to believe than the digital divide may be shrinking.

It is important to point out that this article does not assess how computers affect student learning or performance, but examines the correlates of the decision to provide students with access to classroom computers. In other words, it considers why some urban systems are more likely than others to provide access to a resource that nearly all educators and policymakers deem vital.[3] Access to computers does not necessarily mean that students will learn to use them effectively, but access is an indispensable first step in achieving the goals of computer literacy and technological competence.

Data and Methodology

The data examined in this article are from the 1995 national survey of 85 urban school districts conducted by the Council of Urban Boards of Education (CUBE).[4] This is the most reliable, recent, and systematic data on computer provision (as well as many other subjects) available for a large sample of urban districts. It is unique in its attempt to collect concrete and consistent measures of technology utilization from so many school districts

[3] Although see Hanushek (1986, 1989, 1998), Hedges, Laine, and Greenwald (1994), and Greenwald, Hedges, and Laine (1996) for the more general debate over whether resources affect student achievement.

[4] The CUBE survey is normally conducted triennially, but it has not been conducted since 1995.

in so many states. This information is coupled with school district–level demographic and financial data provided by the 1990 U.S. Census (NCES, 1994).[5]

The model is largely based upon that used by Hess and Leal (1999) to examine 1990–1991 computer provision in a smaller sample of urban districts. Theirs is the only previous attempt to quantitatively examine the urban digital divide, and it found that a larger percentage of African American students in the school population was negatively associated with computer-enhanced instruction, although poorer districts were actually associated with more. Because an explosion in the use of school technology took place throughout the 1990s, it is not clear how representative their data may be of more recent trends. It is important to note that we do not exactly replicate their study, however, as the dependent variables for use of computers in the classroom are somewhat different in the two articles.

The use of a largely urban data set limits our ability to draw conclusions applicable to all American schools, however. First, the range of some explanatory variables is inevitably limited, as an urban-suburban data set would have more variation on a number of dimensions. Second, it limits the larger generalizability of our findings, as it is possible that different dynamics characterize inequities between suburban and urban districts. Although a comparison of the urban-suburban digital divide would be valuable, there are no appropriate data sets encompassing both locales. Our findings may therefore provide some hypotheses to help inform thinking about urban-suburban disparities, but the findings cannot be used to determine the extent of or to explain their causes.

It is also important to note that our data on the racial digital divide is across but not within school districts. We therefore cannot tell whether any given system is distributing its resources inequitably. That is an important question that remains for future research. Access to computers within districts could be skewed by entities such as magnet schools, and some districts may integrate technology disproportionately into gifted or special education courses or simply into some targeted schools, all of which would help determine which particular students receive access to computers.

The first step, however, is to investigate the macro question of whether inequities across districts exist and what variables are associated with a

[5] Missing data required 13 observations to be dropped. Descriptive statistics are as follows and include respectively the mean, standard deviation, minimum, and maximum for all the variables in the data set: student-to-computer ratio, 11.2, 6.56, 3, and 40; improved student-to-computer ratio, 0.82, 0.39, 0, and 1; total enrollment (in thousands), 75.99, 126.9, 6.1, and 919.1; private school enrollment percentage, 0.16, 0.07, 0.04, and 0.34; black student percentage, 0.32, 0.25, 0, and 0.91; Latino student percentage, 0.17, 0.23, 0, and 0.98; median family income (in thousands), 26.5, 49.7, 14.8, and 43.9; college degree percentage, 0.14, 0.05, 0.04, and 0.29; state and local expenditures per student (in dollars), 4,779, 1,227, 2,516, and 8,088; federal expenditures per student (in dollars), 401, 155, 122, and 842; and percentage of board members salaried, 0.46, 0.5, 0, and 1.

community's general provision of technology. This can speak to how the political process leads to different outcomes across communities. A separate—but equally important—question is how districts allocate resources. We are unable to address that in this article, but we recognize its importance, urge research into it, and understand that such findings may modify our findings on the extent and nature of inequities.

Dependent Variables

The two dependent variables in this study were self-reported by districts in the 1995 CUBE survey. The first measures the ratio of students to computers in the district. This is a useful indicator of classroom computer accessibility to the typical student. Values on this variable range from a reported 3 in Norfolk, Virginia, to 40 in Albuquerque, New Mexico. This variable is analyzed using ordinary least squares regression.

The second dependent variable examines whether or not the district had reduced its student-to-computer ratio during the 1993–1994 school year. Districts simply reported whether an improvement had or had not been made, so this variable is analyzed using logit regression.

Explanatory Variables

Four variables measure the racial and socioeconomic characteristics associated with the digital divide. These include the African American percentage of the student population, the Latino percentage of the student population, the income of local families, and the educational level of the adult population.

First, we control for African American percentage of the student population, as white populations have historically denied black children equal access to educational resources. The educational experiences of blacks have been significantly different from those of the broader population because of this history of segregation and exclusion (Henig et al., 1999; Homel, 1990; Katznelson and Weir, 1985; Orr, 1999). This variable tests whether schools have shortchanged black communities when it comes to preparing students for the computer age, as Hess and Leal (1999) found using 1991 data. Black enrollment percentage is measured using the district-level data reported in the Census.

Second, Latinos have also been subjected to extensive educational discrimination. Discriminatory efforts have taken the form of de facto segregation, inequitable school financing, and "second-generation" discrimination (Fraga, Meier, and England, 1986; San Miguel, 1987; Meier and Stewart, 1991). We therefore test whether discrimination exists in the provision of computer technology by controlling for the Latino percentage of school enrollment at the district level, as reported in the Census.

Third, it is hypothesized that communities with higher-income families may be able to supply more external funds to help provide districts with computer equipment. Independent of school district spending, voluntary parental groups often raise local funds for school improvement projects. Districts with higher-income families may also feel compelled to do more to provide classroom computers, recognizing that such families may otherwise choose either to enroll their children in private school or to move to a nearby district. The income of district families is measured using the district-level median family income variable from the Census.

Fourth, educated communities may demand more educational technology, leading to a greater provision of classroom computers. Adults with more education generally place increased demands upon schools for educational quality (Elam, 1978; Elam, Rose, and Gallup, 1994) and are more willing to interact with school administrators and become involved in educational affairs. The community education variable measures the percentage of adults in the school district population that possessed a college degree, as reported in the Census. This is the only variable added to the Hess and Leal (1999) model.

Also included are two measures of school district resources, per-pupil state and local district expenditures as well as federal per-pupil district expenditures. Although separate measures for all three types of spending could have been used, there is no reason to expect that state and local dollars will have different effects.[6] State and local per-pupil expenditures account for more than 90 percent of district spending, offering a good measure of total district resources. This tests the hypothesis that districts with more slack resources will devote some of them to making technology more available to students. Concerns that total per-pupil spending is simply a proxy for district family income are unfounded, as median family income is uncorrelated with total per-pupil spending ($r = .02$). On the other hand, federal dollars tend to be targeted to specific programs, primarily those serving disadvantaged populations. They may consequently have a disproportionate effect on technology provision,[7] although it is not clear whether it would be posi-

[6] Separate analysis showed no evidence that the effects of state and local spending varied significantly.

[7] It would be useful to include a variable for federal dollars that are directly sent to school districts to assist with the purchase of computer technology. We therefore contacted the Technology Initiatives section of the Department of Education, and a representative said that the Technology Literacy Challenge Fund program does provide some such money, although it did not begin until 1997 whereas the data in this study are from 1995. In addition, at least 30 percent of the money goes to professional development, and a significant amount goes to technology-related programs but not the actual acquisition of computers. Most other federal government technology initiatives, such as the E-rate program, did not begin until after 1995. Although Title III of the most recent Elementary and Secondary Education Act (ESEA) included technology assistance (through Goals 2000, Regional Technology in Education Consortia, and Technology Innovations Challenge Grants), the outlays were relatively small and were more likely to fund items like technology planning and technical advice, not

tive or negative. Both variables are measured using school district expenditure data provided by the Census.

We also controlled for three other variables. One was total district enrollment, as larger districts may enjoy economies of scale when it comes to procuring computers. Alternatively, the sheer number of computers needed in larger districts might make it more difficult to provide students with machines.

The second is a measure of the percentage of district students enrolled in private schools, as calculated based upon Census data. Advocates of the "competition thesis" suggest that more competition from private schools will compel public schools to respond in order to maintain and increase enrollment (Hoxby, 1994). One possible response to private school competition may be a public school effort to increase the availability of classroom technology, both because such provision is deemed educationally sound and because it is a visible action that will send a clear signal to parents.

Finally, using data from the 1995 CUBE survey, the model controls for whether school board members are compensated. Compensation is a useful proxy measure for legislative professionalism,[8] and both professionalism and heightened competition may increase board emphasis on providing computer access: professionalism because board members have more opportunity to become informed about educational technology, and competition because board members may be more concerned about responding to public demands for classroom technology.

Unlike the Hess and Leal (1999) study, this article does not include a variable measuring the size of the school board. This is both because they found the variable to have no significant effect and because the justification for the measure was unclear.[9]

The first regression model, explaining the pupils-per-computer ratio, is therefore:

$$\begin{aligned}&\text{Student-to-Computer Ratio} = \alpha + b_1\text{BlackEnrollment\%} + \\ &b_2\text{LatinoEnrollment\%} + b_3\text{MFIncome} + b_4\text{College\%} + \\ &b_5\text{StateLocalPerPupilFunding} + b_6\text{FederalPerPupilFunding} + \\ &b_7\text{DistrictSize} + b_8\text{PrivateEnrollment\%} + b_9\text{SalariedSchoolBoard} + \varepsilon\end{aligned}$$

The second regression model, explaining whether or not districts improved their student-to-computer ratio in 1993–1994, is:

computer hardware or software. Title I money has often been used by districts to purchase technology, but the federal government does not keep track of this. In sum, the representative said there is "no list" of how much money the federal government has provided to school districts to buy computers for the time period of our study.

[8] Fiorina (1997) has used salary as a measure of professionalism in the congressional realm, and there is no reason to believe it would not apply at the school board level.

[9] Whether or not it is included in the models makes no difference in the results obtained.

TABLE 1

OLS Regression of Model on the Student-to-Computer Ratio

Variables	Ratio of Students to District Personal Computers[a]
Constant	8.051
	(8.939)
Median family income (in thousands)	0.150
	(0.259)
College graduate percentage	26.466
(from 0 to 1)	(21.887)
Black student percentage (from 0 to 1)	9.711*
	(5.541)
Hispanic student percentage (from 0 to 1)	–4.191
	(5.854)
State-local expenditures	–2.107**
(per pupil, in thousands)	(0.824)
Federal expenditures	13.046
(per pupil, in thousands)	(9.994)
District size (in ten thousands)	0.054
	(0.080)
Private school enrollment percentage	–19.905
(from 0 to 1)	(17.447)
Salaried school board members (dummy)	0.876
	(1.633)
Observations	62
Adjusted R^2	0.12

[a]Lower numbers represent more favorable ratios.

*** $p < .01$. ** $p < .05$. * $p < .10$.

$$\text{Improvement in Student-to-Computer Ratio} = \alpha + b_1\text{BlackEnrollment\%} + b_2\text{LatinoEnrollment\%} + b_3\text{MFIncome} + b_4\text{College\%} + b_5\text{StateLocalPerPupilFunding} + b_6\text{FederalPerPupilFunding} + b_7\text{DistrictSize} + b_8\text{PrivateEnrollment\%} + b_9\text{SalariedSchoolBoard} + \varepsilon$$

Results

Table 1 shows the results from the first model, in which the dependent variable is the ratio of computers to students. The African American student percentage is associated with a higher student-to-computer ratio ($p < .10$). Substantively, a 10 percentage point increase in African American enrollment was associated with an increase of one in the student-to-computer ratio. This constitutes evidence of a digital divide between urban districts with more African American students and other urban districts, though the substantive significance of this gap is not extreme.[10]

An important consideration is whether race-based inequity has changed over time. One approach is to compare the above results with those reported by Hess and Leal (1999), who found that a 10 percent increase in African American student enrollment was associated with just over 5 percent fewer students receiving computer-enhanced instruction in the 1990–1991 school year.[11] An analysis of the more recent data finds that a 10 percent increase in African American population is associated with 2.5 percent more students per computer.[12] In other words, these findings suggest that the racial digital divide fell by roughly half over the interval.[13]

District spending also revealed some modest effects in the anticipated direction. An additional $1,000 in state and local spending yielded an improvement of about two students per computer in the student-to-computer ratio ($p < .05$). This provides some additional evidence for an interurban digital divide, with higher-income districts providing somewhat more classroom technology. It generally makes sense that schools with greater resources are more likely to buy additional goods and services, ranging from computers to building maintenance to school supplies.

Of the other demographic "digital divide" variables, income, education, and Latino enrollment percentage are all statistically insignificant. Both Latino student percentage and median family income generated very small coefficients and modestly sized standard errors, thereby providing some confidence that their effects really are small or nonexistent. Community

[10] It is also important to note that the black student variable in Table 1 is somewhat sensitive to certain changes in the model. When the highest student-to-computer ratio observations are deleted, the variable drops to statistical insignificance ($p < .13$). We report the results with all observations because there must be clear and convincing reasons to delete data, but the alternative specification further reinforces the modest nature of the observed divide.

[11] The dependent variables in this study and the Hess and Leal (1999) study are not identical, because the CUBE changed the questions it asked districts. There seems little reason, however, to expect that black student population percentage would have a significantly different association with student-to-computer ratio than with the percentage of students receiving computer-enhanced classroom instruction.

[12] We calculate this by taking the worsening of the student-to-computer ratio associated with an increase of 10 percentage points in black student enrollment, then determining how much of a change that represented. A 10 percentage point increase in black enrollment was associated with a 0.9 worsening of the student-to-computer ratio. Student-to-computer ratios in the sample districts ranged from 40 to 4, so a 0.9 worsening of the ratio represented a fall of about 2.5 percentage points along that 36-point range.

[13] On the other hand, this article can address only the relative nature of the digital divide and not whether absolute levels of computer instruction have increased for any group of students. It is possible that the absolute level could have increased over the three-year period for black students, although not as much as for nonblack students. Such a divide would still be important, however, because it might serve to put black K–12 students at a competitive disadvantage in the marketplace and in institutions of higher learning.

TABLE 2

Logit Regression of Model on Reductions in the Student-to-Computer Ratio

Variables	Improvement in Ratio of Students to Computers[a]
Constant	6.268*
	(3.601)
Median family income (in thousands)	–0.011
	(0.011)
College graduate percentage (from 0 to 1)	–8.846
	(9.538)
Black student percentage (from 0 to 1)	7.078**
	(3.432)
Hispanic student percentage (from 0 to 1)	3.085
	(2.565)
State and local expenditures (per pupil, in thousands)	0.721
	(0.463)
Federal expenditures (per pupil, in thousands)	–11.190**
	(5.170)
District size (in tens of thousands)	–0.083
	(0.277)
Private school enrollment percentage (from 0 to 1)	–6.486
	(8.274)
Salaried school board members (dummy)	–1.311
	(0.789)
Observations	72
Percentage correctly predicted	87.5
Proportional reduction in error	31%
Adjusted R^2	0.23

[a]1 = improved ratio; 0 = no improvement.

***$p < .01$. **$p < .05$. *$p < .10$.

education generated a very large standard error, so it is difficult to determine how confident we should be that there are no effects from this variable.

Table 2 shows the results from the second model, explaining whether districts reported an improving student-to-computer ratio during 1993–1994. The results in Table 2 are consistent with the above observation that the racial digital divide appeared to shrink during the 1990s. Black student enrollment was significantly associated ($p < .05$) with whether districts reported an improvement in the student-to-computer ratio, but this time the effect was positive. In other words, districts with a larger percentage of black students had a worse than average student-to-computer ratio in 1994 but were improving their ratio more rapidly than other districts.

Community education, median family income, and Latino enrollment were again not significant. Federal per-pupil spending was associated with a significant worsening ($p < .05$) of the student-to-computer ratio, which might superficially suggest that federal support somehow caused districts to reduce computer availability. The more likely explanation is that the districts targeted by federal aid happen to be among the neediest and most troubled and that federal aid was not enough to counteract this relative deficit.

Lastly, there was no support in either regression for the "competition thesis." Some have suggested that greater competition from private schools will cause public schools to respond in order to maintain enrollment (Hoxby, 1994), and one potential response to such competition is to increase the availability of classroom technology. The percentage of students in private schools was not, however, associated with a lower student-to-computer ratio or with a recent decrease in this ratio.

Conclusions

Much of the attention paid to educational technology focuses on the gap between suburban and urban districts. We suggest that it is also important to consider variation among urban districts. If significant gaps exist between urban communities, then remedies that do not acknowledge such inequities may reinforce or aggravate them. This article does find some evidence of racial and financial inequities as well as indicators that urban schools are addressing the racial digital divide.

First, there appear to be racial inequities in computer provision. Students in districts with a larger percentage of black students had less access to classroom computers. This is also consistent with the previous Hess and Leal (1999) findings, although the dependent variables in the two studies are somewhat different. On the other hand, the degree of black student deprivation may have fallen significantly from the early to mid-1990s. A comparison of the substantive significance of the black student variable in this article and the Hess and Leal (1999) study suggests that the racial digital divide has decreased by approximately 50 percent. One reason for the apparent decline is suggested by Table 2, which demonstrated that although none of the class-based variables were associated with improvements in computer provision, districts with more black students made more progress than their peers.

There is no evidence that community education, community income, or Latino population affected classroom computer provision. Nevertheless, there is evidence that financial inequity does have an effect, because Table 1 showed that districts spending more per capita also had lower student-to-computer ratios. Policymakers should be concerned that regardless of where the money originates, children in schools with relatively lower funding are likely to receive less adequate computer instruction. Additionally, Table 2 does not suggest that schools with relatively lower expenditures have made efforts to improve the student-to-computer ratio.

The above discussion does not mean that these signs of improvement in the racial digital divide still hold, that there was not an urban-suburban divide in the 1990s, or that more equitable computer provision necessarily translated into equitable utilization or training. All of these points will require additional research. It is also important to recognize that the data are limited because of their age, especially given the pace at which technology changes. However, this data set is the most current and comprehensive study of urban districts available; the choice is therefore to use this survey or to neglect to quantitatively examine this important question while waiting for optimal data.

There is also a need to examine whether these findings extend to other kinds of technology provision. Moreover, simple access is not the objective of classroom technology. It is important to understand whether some districts are making better use of educational technology or providing students with better training than do others. All of these questions require additional research and increased efforts to collect systematic data on technology efforts and performance across a broad swath of school districts. We hope that this article will help to spur data collection and scholarly analysis in this area.

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