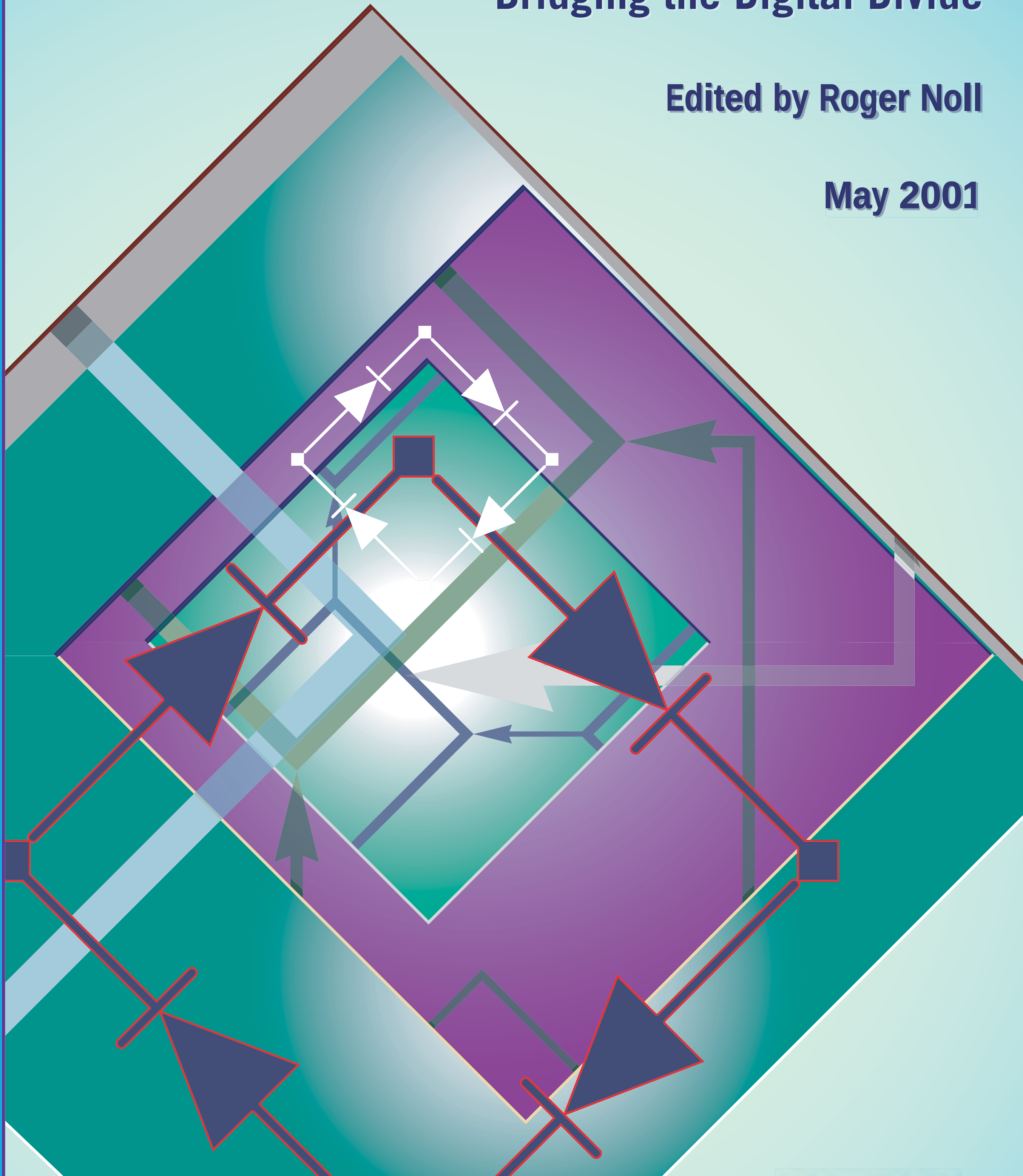
Critical Path Analysis of California's S&T Education System:

Bridging the Digital Divide

Edited by Roger Noll

May 2001



CALIFORNIA COUNCIL ON SCIENCE AND TECHNOLOGY

Bridging the Digital Divide

A Report Prepared for
The California Council on Science and Technology

editted by Roger G. Noll
Stanford Institute for Economic Policy Research
Stanford University

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The California Council on Science and Technology is a nonprofit organization established in 1988 at the request of the California State Government and sponsored by the major post-secondary institutions of California, in conjunction with leading private-sector firms. CCST's mission is to improve science and technology policy and application in California by proposing programs, conducting analyses, and recommending policies and initiatives that will maintain California's technological leadership and a vigorous economy.

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ACKNOWLEDGEMENTS

The California Council on Science and Technology relies on the active participation of many of the state's science and technology leaders. For this project, we have also greatly benefited from the support of civic-minded groups and individuals.

First, we wish to acknowledge Hitachi Ltd. for the exceptional public service to the state and the nation through their public policy forums. In October 1986, Hitachi Ltd. Established a California based public affairs office in Los Angeles. Headed by senior representative Tetsuo Saito, Hitachi's public affairs objectives included the sponsorship of issues and events important to Americans and Japanese. In 1987, Hitachi began sponsorship of a biennial Public Affairs Forum focusing on pressing issues confronting the state such as transportation, air quality control, health care, safe communities, new media and the family. Through their financial support and unflagging interest, Hitachi served the role of instigator and catalyst for this work.

CCST also acknowledges the support of the Hewlett Foundation for enabling us to ensure that this work becomes part of the larger workforce analysis project we are working on.

We were fortunate to have CCST Fellow Roger Noll, Morris M. Doyle Professor of Public Policy, of the Department of Economics at Stanford University, chair and moderate the conference. Professor Noll was the primary driving force for developing the program. We also thank Kathleen Sullivan, dean of Stanford's Law School, and Margaret Jane Radin, co-director of the Stanford Program in Law, Science & Technology for moderating the sessions.

The speakers are also to be thanked for giving up their weekend to present detailed and insightful analyses of an important social issue.

Finally, we acknowledge the invaluable planning and logistical assistance we received from, Dafna Baldwin, Deborah Carvalho and Michelle Mosman of SIEPR, Catherine Nardone and Sandy Giraud of the Stanford Law School, and Sue Harris and Donna King of CCST.

Bridging the Digital Divide

Introduction

On December 9, 2000 an extraordinary group of over 120 people gathered at Stanford University for the California Public Affairs Forum sponsored by Hitachi Ltd. The forum focused on the digital divide, an issue that is frequently used as a lever in policy recommendations for telecommunications and education reform. We are aware that as technology expands its reach into all aspects of our lives, the difference between those of us prepared and capable of using the new tools and those of us left behind is increasing. The world is transitioning to a digital economy. The question is does this technological gap matter, and, if so, what should we do about it?

To develop the program for the forum, the California Council on Science and Technology (CCST) teamed the Stanford Institute for Economic Policy Research (SIEPR), and the Stanford Program in Law, Science & Technology. CCST Council Member Roger G. Noll, a professor of public policy at Stanford, chaired and moderated the forum, along with Kathleen Sullivan, dean of Stanford's Law School, and Margaret Jane Radin, co-director of the Stanford Program in Law, Science & Technology.

Forum panelists discussed the relationships among the education system, facilities for universal communications, and the issue of equal access to software. Speakers from government, academia, industry, community and nonprofit organizations repeatedly emphasized that Internet access is not a luxury, but a necessary component of living. It is a tool to increase productivity. Access to the Internet does not just allow you to do online shopping: it gives you the ability to access applications for life insurance, to find out about political candidates, to access information about medical treatments, and to learn about bus routes. Some speakers said that being cut out from Internet access is as significant as being cut out from having a telephone.

Speakers highlighted the fact that there are many digital divides, including global geographic divides and a divide between affluent and non-affluent households. There is also an age divide, a language divide, a gender divide, and a divide among small businesses. As many speakers pointed out, however, universal access to the Internet, even when physically possible, does not ensure that all sectors of the population will be able or willing to take advantage of the Internet.

Forum speakers emphasized that counting computers, or even counting computer Internet access, is not enough to gage if the digital divide is being bridged. We must ask if people are connecting in an effective way. In fact, counting computers may give erroneous measures. For example, we are aware that the number of devices with a Uniform Resource Locator(URL) is rapidly increasing. People will access the Internet from their cars, Personal Digital Assistants(PDAs), Gameboys, and telephones. They will also access by wireless and landline telephony.

For this forum publication, we asked several of the forum speakers to provide details of each of the major components used to describe and measure the digital divide. We also asked speakers for their perspectives on the current policy debate and for policy recommendations.

The first paper is entitled "The Digital Divide, Measurement and Policy Issues" by Stanford Researchers, Roger. G. Noll, Dina Older-Aguilar, Richard R. Ross, and Gregory L.

Rosston. Noll et al. provide factual background and information describing the digital divide. They review research findings and discuss policy issues on the magnitude of the information technology gap, the patterns of use of information technology(IT) by different population groups, and the use of IT in secondary education. Their data documents the growth in computer ownership and Internet use across socioeconomic and ethnic groups. Their analysis shows that for every social group, computer access and Internet use is growing. However, the gap between different groups is increasing. The final part of their paper looks at IT and education. Here the authors present data on measuring the success of computer and Internet use in education, a theme that is picked up in a later paper by Roy Pea.

The second paper is on "Universal Service, Equal Access and the Digital Divide" by Robert W. Crandall, Senior Economist at the Brookings Institution. The author shows the relationship between the digital divide and U.S. telecommunications policy. Crandall describes recent federal telecommunication reforms on universal service and equal access, discusses the impact of past decisions, and makes projections for the future. The author concludes that rate distortions and subsidies are biasing the industry. Needy households are not targeted for help. Crandall suggests that allowing market forces rather than federal intervention drive the telecom industry will result in a more balanced approach.

The third paper is on "Technology, Equity and K-12 Learning" by Roy D. Pea, Director of the Center for Technology in Learning, SRI International. In this paper, Pea describes and discusses recent data on how equitable access to information technology and the Internet affects K-12 learning. Data on computer use and teacher preparedness are presented. Pea raises a crucial issue: that being connected to the Internet is no longer the point. Access to the right type of information presented in a useful way is far more important. Pea uses phrases like "content divide" and "quality of service divide" to describe the gap.

The final paper is entitled "The Digital Divide: Diagnosis and Policy Options" by Roger G. Noll and Dina Older-Aguilar. In this paper, Noll et al. describes four policy areas that emerged from the forum: universal service, equal access, content diversity, and educational uses of information technology. The researchers suggest ways to ensure that as many people as possible have access to the Internet and that the content is broad enough to have relevance for different social groups. Some of their recommendations include:

- Programs to promote universal access, particularly to low-income households, could be funded through a broad-based tax.
- e-government initiatives - such as agency web sites that allow citizens to access information online - should be expanded. Government policies could assuage fears about privacy invasion through protective regulation.
- Resources need to be devoted to software and teacher training as well as hardware and Internet access. Far more attention needs to be paid to experimenting with the use of information technology in education, and carefully monitoring the results.

As policy directions emerge from the forum, CCST is continuing to develop recommendations for how California's leaders can best respond to this critical issue.

Paul Jennings CCST Chair	Susan Hackwood Executive Director

The Digital Divide

Definitions, Measurement, and Policy Issues

Roger G. Noll, Dina Older-Aguilar, Richard R. Ross and Gregory L. Rosston[1]

Stanford Institute for Economic Policy Research (SIEPR)

Digital Divide is the latest evocative term that refers to differences in access to and uses of information technology that are correlated with income, race and ethnicity, gender, age, place of residence, and other measures of socioeconomic status. According to the Department of Commerce, some people "have the most powerful computers, the best telephone service and fastest Internet service, as well as a wealth of content and training relevant to their lives.... [A]nother group of people ... don't have access to the newest and best computers, the most reliable telephone service or the fastest or most convenient Internet services. The difference between these two groups is ... the Digital Divide."[2]

The purpose of this essay is to provide a brief introduction to the concept of the digital divide and related policy issues. This essay will first broadly outline the nature of the digital divide and the policy issues surrounding it, and then will review the facts and research findings on three main themes: the magnitude of the gap in access to and usage of information technology (IT); the patterns of use of IT, especially among disadvantaged groups; and the uses of IT in elementary and secondary education.

I. DESCRIBING THE DIGITAL DIVIDE

As is apparent from the definition put forth by the Department of Commerce, the digital divide refers to many aspects of information technology, and so cannot easily and simply be explained and measured. Nevertheless, a few generalizations stand at the core of the concept, and have shaped the policy debate.

In part the digital divide is about differential access to hardware. In this sense, the digital divide is a simple extension of the century-old goal of "universal service" in ordinary telephones, which refers to the notion that telephone service is so necessary for full participation in modern life that every household ought to have it. The rise of the Internet caused the policy debate over the definition of core information service to expand so that it now includes computers that are connected to the public telecommunications network. Thus, the first measurement task, summarized in the Section II, is to reveal the patterns of access to IT across socioeconomic groups.

Another aspect of the digital divide refers to software and the uses of information technology. The point of acquiring the hardware to connect to the Internet is to gain access

1 The authors gratefully acknowledge the financial support of the Hitachi Corporation, Ltd. for this research and the support of the Markle Foundation for continuing support of research on communications policy.

2 U.S. Department of Commerce (2000).

to information, entertainment, and other types of software and databases. The extent to which a user can access all of these services is governed in part by hardware including technical characteristics of the user's computer and physical connection to the Internet. In the case of telephones, the core service - audible conversations with others - had the same basic technical features and quality for all users. Product differentiation among consumers was limited to their number of lines and extensions, not the core quality of the service.

For Internet services, consumers are offered several types of network access, from a relatively slow ordinary telephone line to technologies that can transmit much greater amounts of information, and so support far more complex computer services involving such things as full-motion video pictures. Thus, in the digital world, product differentiation in access technology involves considerable variability among consumers in the kinds of information services that, as a practical matter, are or could be made available to them. Of course, the Internet is in its infancy, so that the services that will emerge and the uses that people will make of them - especially members of disadvantaged groups, who generally use IT less intensively - are only just beginning to emerge. The little we know about this issue is also summarized in Section II.

Still another aspect of the digital divide refers to access to the full range of services through the consumer's network connection, and is called the "equal access" issue. In general, the segments of the information technology sector differ substantially in the number and diversity of products that are available to consumers. Both computers and end-user information services are competitive industries, and the latter contains not only numerous commercial ventures but also literally millions of free websites, many of which are maintained by amateurs. But some elements of the contemporary digital information technology system are not yet very competitive, most notably the hardware connecting customers to the network and the operating system software on a consumer's personal computer.

At present, most customers who want high-quality Internet access have very few choices: a telephone company that can supply a Digital Service Line (DSL), a cable television company that can supply roughly the same quality service, and perhaps a wireless company, although high-speed residential wireless access is still in the developmental stage. These high-capacity lines must access the Internet through some form of navigational gatekeeper, called an Internet Service Provider (ISP). In the case of cable television, but not yet telephone companies, high-speed access usually is bundled with an ISP that is affiliated with the cable company. Likewise, almost all home computers use the Windows operating system, which incorporates Microsoft's ISP as the default gateway to the Internet.

The "equal access" problem refers to the prospect that competition among ISPs will be as limited as competition among hardware access alternatives and computer operating systems due to the bundling of access with a designated ISP. The potential problems arising from limited competition among only a few ISPs are, first, that service prices will be high, thereby denying Internet access to households that would be able to afford it at competitive prices, and, second, that ISPs that are affiliated with hardware or operating system companies will disadvantage unaffiliated Internet information service providers, thereby substantially reducing the extent of competition, diversity, and quality in Internet services.

The final element of the policy debate over the digital divide is to identify the specific reasons that society might want to do something to narrow the gap in access to information technology. In part the policy debate is about standards and regulations, such as whether Microsoft should be permitted to bundle Internet Explorer with Windows and whether cable and telephone companies ought to be prevented from channeling their high-speed Internet access customers through their affiliated ISP. But the larger part of the debate is about the extent to which aspects of digital technology ought to be subsidized so that a larger number of customers can afford to use it. In the latter case, especially, the debate quickly focuses on precisely which kinds of information services ought to be ubiquitously available to all citizens.

The presence of gaps in access and usage of IT among various socioeconomic groups is hardly surprising, and raises the core question about the policy significance of the digital divide: why is IT sufficiently special that society ought to intervene to encourage consumer utilization of IT rather than other goods and services that also are possessed and used less extensively by disadvantaged groups? Fundamentally, low income, social and geographic isolation, and poor educational inputs lead to "divides" in all aspects of life. We easily could document a nutritional divide (low socioeconomic status individuals are less likely to have a healthy diet), a residential divide (these households are less likely to have adequate housing, indoor plumbing, and heating), and a political divide (likewise, these households have lower political participation - they do not vote or engage in civic activities as frequently as higher socioeconomic status individuals). The proposed answer to this question is that advanced IT can help disadvantaged individuals overcome these other problems, including the over-riding cause of their disadvantage, which is low income.

The possibility that information technology is capable of vastly improving the economic success and social conditions of disadvantaged groups is not new. In the early 1970s, many visionaries regarded cable television as a good candidate to educate and inform so as to enable consumers to qualify for and to find better jobs, to make better choices as consumers, and to become better parents.[3] The arguments today about the potential of the Internet for elevating the conditions of the disadvantaged have surprisingly large overlaps with this earlier debate.

Probably the greatest attention has been given to educational uses of information technology, especially the use of computers and the Internet in elementary and secondary education. Indeed, the Telecommunications Act of 1996 specifically mentions ubiquitous Internet access from schools as one of the major goals of "universal service" policy, and many states have embarked on ambitious plans to achieve this objective. A great deal of research has been devoted to developing IT for educational purposes and then monitoring its effects on educational attainment. The results of this research are summarized in Section III of this report, and form the basis of the analysis and proposals put forth in the essay by Roy Pea for these proceedings.

3 For example, see Sloan Commission on Cable Communications (1971), which proposed devoting half the channels on cable television systems to various forms of information services (p. 142). A member of the Commission's staff, Ralph Lee Smith, expanded upon this recommendation by writing a book about the range of services that could and ought to be mandatory for cable systems (The Wired Nation, Harper and Row, 1972). Of course, cable television never fulfilled these promises, primarily because these services would have to be subsidized to be provided, and the subsidy costs were very large compared to the cost of cable television (see Noll, Peck and McGowan (1974), pp. 183-207)

II. MEASURING THE DIGITAL DIVIDE

In the past few years a large number of studies have examined the use of information technology in general, and computers and the Internet in particular. These studies employ many different methodologies and reach differing conclusions, but they agree on two core points: ordinary telephone technology provides very near complete, ubiquitous coverage, while the use of computers and the Internet is in its early stages and growing rapidly.

The National Telecommunications and Information Agency (NTIA) has issued a series of reports that use Current Population Survey (CPS) data to examine the questions of computer and Internet access and usage. Other surveys and data gathering rely on different samples that are not directly comparable to the NTIA reports, but are useful for understanding different aspects of Internet connection and usage.

Obviously, a necessary condition for using the Internet and other software is access to a computer. Table 1 presents the information about computer ownership. Computer ownership is growing at an extremely rapid rate, and growth is rapid among all demographic categories.

NTIA data show that ownership of a computer is very likely to lead to Internet use. In 1997, only about half of computer-owning households were connected to the Internet. By 2000, more than 80 percent of those households were connected, while 15 percent more households had a computer. The current difference between the proportion of households owning computers and having Internet connections is about ten percentage points.

The NTIA data also show that the overall household Internet connection rate has more than doubled in three years from 18.6 percent of all households in 1997 to 41.5 percent in 2000 (Table 2). Household Internet connection rates more than doubled for every income group below $50,000 from 1997 to 2000, but fewer than 20 percent of households with incomes below $20,000 have an Internet connection. Household Internet connections have at least doubled since 1997 for every racial category in the NTIA data. In fact, all racial groups now have household connection rates higher than white household connection rates were in 1997. More than one-fourth of older households have Internet connections, nearly triple the rate in 1997.

NTIA also has data on individual Internet connections, as does a Summer 2000 survey by the Pew Internet and American Life Project. Both surveys show results similar to the household data. Connections are higher for people with higher incomes, for whites, and for those with more education. The connection rate for individuals is slightly higher than the connection rate for households because some people have connections at work, school, or a public library but not at home, and because households with Internet connections have more people in the household.

Internet connection rates have increased extremely rapidly, especially compared with the adoption of other communications technologies. Even in 1991, forty years after the first introduction of cable, only 58 percent of television households subscribed to basic cable service.[4]

4 Federal Communications Commission (1999).

Table 1--Computer Ownership of All U.S. Households

	Percent of U.S. Households with a Computer					
	1984	**1989**	**1994**	**1997**	**1998**	**2000**
All Households	8.2	15.0	24.1	36.6	42.1	51.0
Income						
<$5,000	1.6	5.8	8.4	16.5	15.9	21.8
5,000-9,999	1.7	3.7	6.1	9.9	12.3	14.6
10,000-14,999	3.3	4.5	8.2	12.9	15.9	22.0
15,000-19,999	5.3	8.0	11.7	17.4	21.2	28.4
20,000-24,999	8.1	9.6	15.2	23.0	25.7	31.4
25,000-34,999	11.7	14.6	19.8	31.7	35.8	44.6
35,000-49,999	17.0	22.5	33.0	45.6	50.2	58.6
50,000-74,999	22.4	31.6	46.0	60.6	66.3	73.2
>75,000	22.1	43.9	60.9	75.9	79.9	86.3
Race/Hispanic Origin						
White	8.8	16.0	27.1	40.8	46.6	55.7
Black	3.8	6.6	10.3	19.3	23.2	32.6
Asian American and Pacific Islander *Other Non-Hispanic*	8.4	17.6	32.6	47.0	55.0	65.6
Hispanic	4.3	7.1	12.3	19.4	25.5	33.7
Education						
Elementary	0.9	1.9	2.6	6.8	7.9	12.8
Some High School	2.3	4.5	6.0	10.9	15.7	21.9
High School Diploma or GED	5.9	9.1	14.8	25.7	31.2	39.6
Some College	11.3	18.1	28.9	43.4	49.3	60.3
Bachelor's or more	16.4	30.6	48.4	63.2	68.7	75.7
Household Type						
Married Couple w/ Child <18	15.4	23.7	46.0	57.2	61.8	73.2
Male Household w/ Child <18	6.9	16.1	25.8	30.5	35.0	45.6
Female Household w/ Child <18	6.7	9.1	19.3	25.0	31.7	42.9
Family Households w/o Child	5.1	14.8	26.6	36.4	43.2	52.5
Non-family Households	3.7	7.6	15.0	23.5	27.5	34.6
Age						
<25	5.1	8.5	18.1	28.0	32.3	
25-34	9.4	14.5	25.1	40.0	46.0	
35-44	15.5	23.5	34.1	49.0	54.9	
45-54	10.2	22.0	33.6	48.0	54.7	
>55	2.5	6.4	12.7	21.0	25.8	
Income and Race/Hispanic Origin						
White						
<$15,000			9.2	15.4	17.5	22.8
15,000-34,999			18.1	28.0	32.5	40.8
35,000-74,999			40.5	55.1	60.4	68.7
>75,000			61.0	76.3	80.0	87.0
Black						
<$15,000			2.9	6.3	6.6	11.5
15,000-34,999			10.0	18.2	19.4	27.3
35,000-74,999			24.8	40.2	43.7	52.7
>75,000			52.6	64.1	78.0	83.4
Asian American and Pacific Islander *Other Non-Hispanic*						
<$15,000				19.1	32.6	39.4
15,000-34,999				38.5	42.7	53.5
35,000-74,999				62.6	65.6	72.4
>75,000				81.0	85.0	86.9
Hispanic						
<$15,000			3.6	7.8	9.4	12.5
15,000-34,999			9.4	16.6	19.8	27.8
35,000-74,999			30.6	36.8	49.0	55.9
>75,000			60.7	72.8	74.8	76.1

Notes:
1) Data by race for 1984-1997 lists "Other Non-Hispanic" while 1998 and 2000 list "Asian American and Pacific Islander".
2) Data from NTIA 2000 (Figures I-1 and A1-A7), NTIA 1999 (Charts I-14 and A8-A14), and NTIA 1998 (Charts 13 and 15a-c

Table 2--Internet Access of All U.S. Households

	Percent of U.S. Households with Internet Access			Gap Between Given Group and Population as a Whole		
	1997	1998	2000	1997	1998	2000
All Households	18.6	26.2	41.5	0.0	0.0	0.0
Income						
<$5,000	7.2	8.1	16.0	(11.4)	(18.1)	(25.5)
5,000-9,999	3.9	6.1	9.3	(14.7)	(20.1)	(32.2)
10,000-14,999	4.9	7.4	14.2	(13.7)	(18.8)	(27.3)
15,000-19,999	7.0	9.8	19.2	(11.6)	(16.4)	(22.3)
20,000-24,999	9.0	12.1	22.9	(9.6)	(14.1)	(18.6)
25,000-34,999	13.9	19.1	34.0	(4.7)	(7.1)	(7.5)
35,000-49,999	20.8	29.5	46.1	2.2	3.3	4.6
50,000-74,999	32.4	43.9	60.9	13.8	17.7	19.4
>75,000	49.2	60.3	77.7	30.6	34.1	36.2
Race/Hispanic Origin						
White	21.2	29.8	46.1	2.6	3.6	4.6
Black	7.7	11.2	23.5	(10.9)	(15.0)	(18.0)
Asian American and Pacific Islander / Other Non-Hispanic	25.2	36.0	56.8	6.6	9.8	15.3
Hispanic	8.7	12.6	23.6	(9.9)	(13.6)	(17.9)
Education						
Elementary	1.8	3.1	7.2	(16.8)	(23.1)	(34.3)
Some High School	3.1	6.3	14.8	(15.5)	(19.9)	(26.7)
High School Diploma or GED	9.6	16.3	29.9	(9.0)	(9.9)	(11.6)
Some College	21.9	30.2	49.0	3.3	4.0	7.5
Bachelor's or more	38.4	48.9	66.0	19.8	22.7	24.5
Household Type						
Married Couple w/ Child <18		39.3	60.6		13.1	19.1
Male Household w/ Child <18		19.5	35.7		(6.7)	(5.8)
Female Household w/ Child <18		15.0	30.0		(11.2)	(11.5)
Family Households w/o Child		27.2	43.2		1.0	1.7
Non-family Households		17.5	28.1		(8.7)	(13.4)
Age						
<25	17.1	20.5	35.7	(1.5)	(5.7)	(5.8)
25-34	22.0	30.1	47.5	3.4	3.9	6.0
35-44	24.7	34.1	52.3	6.1	7.9	10.8
45-54	25.8	35.0	51.9	7.2	8.8	10.4
>55	8.8	14.6	26.0	(9.8)	(11.6)	(15.5)
Income and Race/Hispanic Origin						
White						
<$15,000		8.9	16.0		(17.3)	(25.5)
15,000-34,999		17.0	31.0		(9.2)	(10.5)
35,000-74,999		39.0	56.7		12.8	15.2
>75,000		60.9	78.6		34.7	37.1
Black						
<$15,000		1.9	6.4		(24.3)	(35.1)
15,000-34,999		7.9	17.9		(18.3)	(23.6)
35,000-74,999		22.2	38.7		(4.0)	(2.8)
>75,000		53.7	70.9		27.5	29.4
Asian American and Pacific Islander / Other Non-Hispanic						
<$15,000		16.4	33.2		(9.8)	(8.3)
15,000-34,999		24.7	43.8		(1.5)	2.3
35,000-74,999		39.9	60.7		13.7	19.2
>75,000		64.8	81.6		38.6	40.1
Hispanic						
<$15,000		3.8	5.2		(22.4)	(36.3)
15,000-34,999		7.6	17.7		(18.6)	(23.8)
35,000-74,999		26.8	41.5		0.6	0.0
>75,000		48.1	63.7		21.9	22.2

Notes:
1) Data by race for 1997 lists "Other Non-Hispanic" while 1998 and 2000 list "Asian American and Pacific Islander".
2) Data from NTIA 2000 (Figures A1 and A9-A14), NTIA 1999 (Charts I-21, I-22, and I-24 through I-27), and NTIA 1998 (Charts 20-23)

Table 3 -- Internet Access by Household Location

	Rural			Central City			Urban		
	1997	**1998**	**2000**	**1997**	**1998**	**2000**	**1997**	**1998**	**2000**
All Households		22.2	38.9		24.5	37.7		27.5	42.3
Income									
<$5,000	5.6	4.3	13.1	6.6	9.5	17	7.7	9.1	16.8
5,000-9,999	2.3	2.9	9.0	4.6	6.8	9.5	4.4	7.2	9.4
10,000-14,999	2.8	6.0	12.5	5.7	8.1	15.4	5.6	7.9	14.8
15,000-19,999	4.5	8.4	19.1	9.6	11	19.2	7.8	10.3	19.3
20,000-24,999	6.5	10.0	21.2	10	14.4	22	9.9	12.9	23.5
25,000-34,999	11.6	15.4	31.5	13.3	22.5	34.6	14.7	20.4	34.9
35,000-49,999	16.0	26.4	41.8	23	31.8	46	22.6	30.6	47.8
50,000-74,999	27.6	38.7	59.5	35.1	44	60.1	33.9	45.7	61.4
>75,000	44.4	53.7	76.6	49.4	59.7	76.1	50.3	62.0	78.0
Race/Hispanic Origin									
White	15.6	23.7	40.9	23.3	32.3	47.1	23.5	32.4	48.3
Black	5.5	7.1	19.9	5.8	10.2	20.1	7.9	11.7	24.0
Asian American and Pacific Islander *Other Non-Hispani*	16.1	24.7	62.1	23.5	33.3	53	26.4	36.5	56.6
Hispanic	7.3	9.8	19.9	7	10.2	21.5	8.9	12.9	23.9
Education									
Elementary	1.2	1.8	6.1	2.2	3.4	8.4	2.1	3.7	7.6
Some High School	2.5	6.1	16.5	2.5	5.2	11.9	3.4	6.4	14.2
High School Diploma or GED	9.2	15.5	31.0	7.9	13.7	25.7	9.8	16.6	29.5
Some College	20.5	29.6	50.0	19.7	26.4	43.6	22.3	30.4	48.7
Bachelor's or more	35.6	47.0	67.7	36.1	47.7	62.3	39.0	49.4	65.7
Household Type									
Married Couple w/ Child <18		33.0	58.3		35.2	55.1		41.9	61.5
Male Household w/ Child <18		14.2	30.3		17	35.3		21.5	37.4
Female Household w/ Child <18		14.5	31.2		13.1	22.8		15.0	29.7
Family Households w/o Child		22.6	37.7		27.5	41		29.0	45.5
Non-family Households		10.2	20.2		20.8	30.8		19.2	29.9
Age									
<25	12.1	13.3	29.8	19.2	22.8	35.5	18.0	22.0	36.9
25-34	15.7	24.2	42.5	22.6	28.8	46.4	23.6	31.6	48.7
35-44	21.0	30.2	50.9	20.9	31.3	46.2	25.9	35.4	52.7
45-54	21.6	30.8	49.6	22.2	30.7	45.4	27.3	36.5	52.7
>55	6.7	12.4	24.6	7.8	13.8	22.2	9.5	15.4	26.5

Notes:
1) For some reason the reports do not give the total numbers for Rural, Urban and Central City households for 1997.
2) Data by race for 1997 lists "Other Non-Hispanic" while 1998 and 2000 list "Asian American and Pacific Islander".
3) Data from NTIA 2000 (Figures A8-A10 and A12-A14), NTIA 1999 (Charts I-21, I-22, and I-25 through I-27), and NTIA 1998 (Char

By 1999, that had increased to 67 percent, a growth rate of about 1 percent of households per year from 1991.

Telephone service took a much longer time to reach a majority of household subscribers. In 1920, more than 40 years after the introduction of the telephone, only 30 percent of American households had telephone service.[5] By 1983, this had increased to more than 90 percent of households. Since then, telephone penetration has increased about 3 percent.

DIFFERENCES BY SOCIOECONOMIC STATUS

Table 2 provides information about connection rates across groups. Differential connection rates have been the center of the discussion about the Internet. The NTIA *Falling Through the Net* reports over the past five years have been very concerned with this issue,

5 Mueller (1997), p-148.

focusing on the differences between those who have connected to the Internet and those who have not.

Internet connection increases with income. The connection rate for the highest income group is around 75 percent whereas the lowest income group connects at a rate between 18 percent and 30 percent. A second differential exists between racial groups. For example, the overall percentages show that Black households connect at roughly half the rate of white households (23.5% vs. 46.1%). However, it is important to consider the effect of income when making these comparisons. Table 2 shows that even correcting for income, Blacks and Hispanics have lower connection rates than white households and Asian American and Pacific Islanders have connection rates that are still higher. These hold true for each and every income level.

While Internet access has increased significantly for all groups, it has increased at different rates, and the difference between access for low-income, Black and Hispanic households and the national average has increased. This means that while both sets were approximately doubling connections, the lower initial level of disadvantaged groups means that the differential has increased. But if Black, Hispanic, and low-income household connection rates continue their rate of increase, they will begin to catch up to the national averages. One can interpret these statistics in different ways: the gap between different groups is increasing, but every group is increasing its Internet connection rate and the growth rate is highest among disadvantaged groups.

According the Pew study (Lenhart 2000), those who plan to get Internet connections also differ by income. Nearly three-quarters of high-income households that are not currently connected plan to connect, whereas 38 percent of households with incomes below $30,000 plan to connect. Even though a smaller percentage of low income households plan to get online, because more are not connected, low-income households will connect more rapidly and reduce the gap between high-income and low-income household connections, assuming the Pew results are accurate reflections of future connection rates.

The policy debate also focuses on making sure that rural America does not get left behind in the transition to a digital economy.[6] The third column in Table 3 shows that 38.9 percent of rural households are connected to the Internet, 2.6 percent below the nationwide average (41.5 percent from Table 2), up from 22.2 percent in 1998. This increase of more than 16 percent of rural households caused the differential between rural connections and the national average to fall from 4 percentage points to 2.6.[7] At all income levels, the connection rates of rural residents are nearly equal to connection rates of the country as a whole.

It is not surprising that rural connections to the Internet are comparable to the nation as a whole. Downes and Greenstein (1999) undertook an extensive research project to calculate the percentage of households in the U.S. that had the ability to connect to an Internet service provider with a local (non-toll) telephone call. They found that nearly 92 percent of the country could do so in early 1998. These results reflect the cost structure for providing dial-up Internet service. For simple, content-free service, scale economies are not substantial.

6 NTIA (1995) "Falling Through the Net: A Survey of the 'Have Nots' in Rural and Urban America" was concerned specifically with this differential.

7 Lenhart, A. (2000) presents survey data showing a 10 percent difference (57% vs. 47%) between rural and urban areas. Much of that she claims is due to a difference in computer usage between rural and urban residents.

Hence, areas with low population density do not face substantially higher costs of connection, and so are unlikely to be especially disadvantaged in access and usage other than for reasons that are captured by measures of socioeconomic status.

The second three columns in Table 3 show Internet connection data for central city households.[8] All central cities have many local Internet service providers. The connection rates for each income level are very similar to the rural connection rates. However, the overall connection level for central city households is below that of rural areas, presumably because central cities have a higher proportion of lower income households. Internet connections for the lower income levels at least doubled from 1997 to 2000. In contrast to the rural households, the connection rates in central cities grew at a slower rate than the nation as a whole.

The comparisons between rural and central city households provide some important insights into the possible causes of differential connection rates and shed light on the effectiveness and appropriateness of various policy alternatives. At current rates for Internet service and local telephone service, the opportunities to connect to the Internet appear to be similar for residents of urban and rural areas. This may change if high-speed access becomes the norm for Internet access, for current technology cannot provide efficient, high-speed access to rural areas. Other than the telephone service, rural Internet service is not subsidized. If rural high-speed access begins to be subsidized, it is important to understand that taxing urban subscribers to subsidize rural areas will increase prices in other areas. Given that central cities have lower Internet subscription rates than rural areas, this cross-subsidization could have the perverse effect of lowering connection rates in the areas where Internet penetration is lowest.[9]

INTERNET USAGE

The way that individuals actually use the Internet will have important implications for any public policy actions that seek to increase the penetration of the Internet. Many argue that connection to the Internet is vital to participation in the digital economy and the democratic process.

The UCLA Internet Report (2000) examines how people use the Internet, and finds that people who have more experience online spend more time online working at home, looking for new Internet sites, and making investments. People with less than a year of experience online spend more time playing games and pursuing hobbies. At least two possible interpretations of these data are possible. The first is that people learn more about the possibilities of the Internet over time and feel more comfortable with the Internet as a tool as they gain experience. The alternative interpretation is that more serious Internet users have a higher demand for the Internet and signed up for service earlier. If the latter interpretation is correct, subsequent subscribers will tend to be less commercially oriented in their Internet use. The data presented in the survey provide no basis to distinguish between the two alternative interpretations.

High-speed Internet access has become an important feature of many policy debates. It was a central concern in the AOL-Time Warner merger proceeding at the Federal Trade

8 Central city is defined to be the largest city within a metropolitan area.

9 Rosston and Wimmer (2000) discusses the costs to low-income urban residents from an untargeted rural telephone subsidy.

Commission, and the Federal Communications Commission has an open proceeding asking questions about whether they should take action to regulate access to high speed cable data lines. Most residential consumers essentially have two means to get high-speed access now - either from their local cable company or from the use of telephone lines to get digital subscriber line (DSL) service. In addition, new technologies for high-speed wireless access are, if one is to believe wireless carriers, about to become widely available. DSL service is limited to customers who live within about three miles of the central office telephone switch serving the customer, and thus can not provide a good alternative for customers in rural areas where loop lengths are significantly longer; however, new technologies are expected to extend the reach of DSL to about eight miles. Cable modem service is an asynchronous service using a shared loop so that extensive use by neighbors can degrade service quality unless cable systems allocate more channels to internet access (and fewer to television).

High-speed access service provides the potential for advanced services like streaming video and other high-value content. NTIA found that 10.7 percent of Internet connected households had high-speed connections. This ranged from slightly above 7 percent for low income households to almost 14 percent for high-income households. None of these are extremely high, low-speed dial up represents the vast majority of connections in all income categories.

We are still at an early stage in the development of the Internet and corresponding content. It is clear that computers, connection and content are complementary goods. Owning a computer is more valuable because of the ability to connect to the Internet. And connecting to the Internet is made valuable because of the content available. As each becomes less expensive and better, demand for the complements will increase and as high-speed connections increase, there will be more specific additional high-speed content. With more variety of content, more specific content and content tailored to specific connection methods, the value to connecting to the Internet should increase.

This increase in usage may highlight more issues relating to differential access to the Internet even among those who are connected. It may be the case that some households have access to more and better services, much like some households subscribe to cable and pay cable services. Other issues like whether the network operator (e.g. cable modem provider) can limit available services or affect competition are likely to arise as well.

REASONS FOR DECLINING TO USE THE INTERNET

Analysis of the connection differentials between different groups and any resulting policy prescriptions need to take into account reasons why people are not connected to the Internet. The Pew Internet and American Life Project released the results of a survey in September 2000 that provides some insight into these questions. They found that "57% of those without Internet access say they do not plan to log on."[10]

The survey results find that these attitudes depend upon age - older Americans are much less likely to desire to be connected than younger people. The majority of those not online who are under 50 years old plan to connect to the Internet. The report goes on to state that "[s]ignificant numbers of non-users cite issues besides the cost of computers and Internet access as problems when they think about the online world."[11]

10 Lenhart (2000).

11 Lenhart (2000). p-3.

Pew looked at Internet users who were demographically comparable to people who did not use the Internet. They examined what these users did on the Internet and found that recreational activity and e-mail were important features. "This analysis suggests that high-minded pitches about the civic, educational, or even commercial virtues of the Internet would probably not be enticing to those in the Never group. Rather, it suggests that Nevers might be more open to the idea of going online if they are convinced that the Internet is useful, entertaining, and not-too-difficult to use."[12]

Finally, Pew divided the group of non-connected people into those who have never had a connection and those who previously had a connection, but terminated it. Slightly more than 10 percent of the non-connected people previously had been connected. The previously connected users are slightly more minority, have less education and lower income than current Internet users, but are reflective of the overall population. Only 11 percent of these previously connected users claimed that they gave up their connection because it was too expensive. No longer owning a computer and changing jobs were the top two reasons.

STUDIES OF UNIVERSAL SERVICE POLICY

Existing universal service policies for telephone service provide two types of subsidies. The first is "lifeline" subsidies for households with low incomes, and the second is a general policy to set rates below cost in rural areas and small towns. Both subsidies are then paid for by setting other prices above cost, especially for long-distance calls and business access. Virtually all economists who have studied telecommunications universal services subsidies agree that this subsidy system is deficient in many ways. In general the criticisms fall into three categories: ineffectiveness, inefficiency, and inequity.

First, some studies conclude that universal service subsidies are ineffective.[13] Generally, these studies show that local telephone service is extremely price inelastic, so that subsidies of basic telephone service have little or no effect on telephone penetration because almost all households would subscribe to telephone service even at substantially increased prices. Policy actions relating to Internet connection should consider the price elasticity of connections, and the surveys about internet use do not support the conclusion that price is an important factor influencing internet usage.

Second some studies argue that universal service subsidies are inefficient.[14] The telephone service that is subsidized is basic monthly access, which is price inelastic, while the revenue to provide subsidies comes from taxes on more elastically demanded services such as long distance calls. As a result, the demand for the elastic services is muted at the same time that there is little increased in demand for the inelastically demanded services. Hausman, Tardiff and Belinfante (1993) show that because of the higher elasticity of demand for long distance service, it may be possible that connections actually decrease because of the long distance taxes.

Finally, universal service subsidy programs are criticized because they transfer substantial wealth among households regardless of income.[15] Telephone subsidies transfer purchasing power from urban to rural customers, from business to residential customers, and from those who make many long distance calls to those who make few long distance calls. These

12 Lenhart (2000) p-9.

13 See e.g. Kaserman, Mayo and Flynn (1990).

14 See eg. Crandall and Waverman (2000).

15 See eg. Rosston and Wimmer (2000).

transfers are not predominantly from high-income to low-income customers. Many low-income customers live in urban areas and many high-income customers live in rural areas that receive high-cost subsidies, while households with the same income display greater variance in long-distance calling than the average difference between high- and low-income households.

POLICY IMPLICATIONS

The Internet is growing at an exceptional rate, much more rapidly than telephones or cable television did at similar stages in their histories. Not surprisingly, socioeconomic groups differ in their adoption rates of IT. The differences appear to be primarily due to income, although there are also racial differences even when income is held constant.

Given the rapid adoption of the Internet, it is not clear how these differences will change over the long run, or even over the next few years. It is possible that these differences will narrow significantly as more people conclude that the Internet is valuable and decide to connect. This may occur because more and different content is developed, because prices (for connection and computers) decrease, or simply because people become more comfortable with the idea of using the Internet through learning and exposure.

Another possibility is that persistent gaps will remain, just as there are for cable television and, to a lesser degree, telephone penetration. Some telephone penetration differences remain despite significant subsidy programs, both for rural high-cost areas and also for low-income households. Because lifeline telephone rates are very low and demand is price inelastic, it seems unlikely that even cutting the price to zero would have much of an effect on telephone access.

Given that the subsidies for telephone service are inefficient and that rural Internet connection is higher than inner city connections, providing a general subsidy for rural Internet connections will subsidize many people who are likely to subscribe in any case, and so is not likely to be a very effective use of scarce resources. Instead, if Internet access is to be subsidized, the subsidies should be targeted at those who would not otherwise subscribe because of cost, as with lifeline service. Because some Internet service providers offer free or very low-cost connections, programs designed to educate consumers about low cost alternatives are likely to have a larger effect on total Internet use than a program that copies the existing policy to provide a general subsidy to high-cost areas. The issue of possible subsidies for high-cost Internet connections present similar tradeoffs in that, with present technology, providing high-speed connections to rural areas will be extremely expensive compared to the cost of subsidies for low-income consumers in urban areas.

Based on the survey results, many people might benefit from education about where to acquire Internet-ready second-hand computers, and about how to use computers and the Internet. In addition, consumer education programs might help reduce the uncertainty about the use of the Internet. Such programs would probably be relatively low cost compared to the subsidies for rural high-cost telephone service. In addition, given that the survey results indicate that younger people are much more familiar and comfortable with the Internet, such programs would not have to grow over time. Instead, as computers and Internet connection proliferate, such programs could be reduced, rather than increased as a connection subsidy would automatically.

III. IT AND EDUCATION

This section reviews the research on an important component of the digital divide, the extent to which differences in computer use and access create unequal educational opportunities and increase the achievement gap between high and low-performing students. The effect of computer use on this gap will be determined both by computers' inherent effectiveness as a learning tool and by differences in use and implementation across student groups. In addition, the effectiveness of IT as an education tool may differ among groups of students, in which case widespread adoption of the technology could either increase or decrease outcome disparities.

Given the inherent usefulness of a technology, the implementation strategy for using it will affect the realized effect on both the level and distribution of student achievement. Poor implementation will attenuate outcome gains for all students. In addition, socioeconomic characteristics may affect access and implementation experienced by an individual child. If the educationally disadvantaged are exposed to less useful applications or less adept teachers, existing differences in outcomes across groups will be exacerbated by computers.

Starting with school-based computer use and following with home use, we examine what is known about the potential usefulness of computers, the limitations created by insufficient access and sub-optimal implementation and the interactions between individual characteristics and both the potential and realized benefits of computer use. We then conclude with a discussion of the cost effectiveness of computers as an educational tool and the resulting policy implications. First though, we will provide context for the review by briefly discussing what is generally known about the factors important to children's educational success.

HOME- VERSUS SCHOOL-BASED EDUCATIONAL INPUTS

Although proponents of computer-aided learning have high expectations for the ability of computers to increase student performance, the history of education research suggests that the main factor influencing educational performance is a student's socioeconomic background, and that external inputs have relatively little power to explain differences in children's achievement. In 1966 the Coleman Report, a national study of schools and children, was unable to find a strong relationship between observable school inputs and children's educational outcomes (Coleman et al., 1966). Subsequent research has found evidence that schools differ in quality and in their effect on student achievement, but it is still hard to predict which schools will be better at improving children's outcomes by looking at observable resources such as school spending, teachers' education or class size (Hanushek, 1997). It is reasonable to infer that like other educational tools, computers will have a limited effect on children's outcomes.

In contrast to the literature on school inputs, family characteristics are highly correlated with student outcomes (Haveman and Wolfe, 1995). At-home contributions to education seem to play a large role in children's learning. Family and individual characteristics also affect outcomes through their interaction with school-based resources. Such interactions are present when family income, ethnicity, gender, or ability level directly moderates a child's response to an educational input. Interactions are also generated when parents with different characteristics differentially affect the way in which resources are used. Individual characteristics can also affect an input's effectiveness if teachers use the resource differently based on a child's gender, ethnicity, ability or income.

The limited potential of school-based resources, the importance of in-home activities, and the indirect effects of individual characteristics are all particularly relevant to a consideration of the digital divide. While computers may be important educational tools, their limited potential should be taken into consideration when taking on the costs of increasing computer usage in schools. Computer technology should also be examined as part of home investments into children's education. The general importance of home inputs should direct attention to this setting even though the weight of research is focused on school-based use. Finally, because computers can be used in such different ways, they are especially subject to the kind of indirect effects that individual characteristics have on the effectiveness of educational inputs.

With this background in place we now move to an analysis of the potential effect of computers, and the digital divide on disparities in educational outcomes.

OVERALL EFFECTIVENESS OF COMPUTERS

In order to assess the raw potential of computers as learning tools it is useful to examine the effect of programs that were carefully and, hopefully, optimally implemented. The bulk of research into the effectiveness of computers is of this nature, focusing on a specific application or implementation. The study of specific applications may yield an upper bound estimate of the effectiveness of computer use and can also provide information on the elements of computer applications that increase effectiveness. Many of these studies show evidence that computer use can increase measured outcomes.

Surveys summarizing this literature[16] come to different conclusions regarding the overall evidence on computer's effectiveness as learning tools. Sivin-Kachala and Bialo (1999) assert that, "education technology has demonstrated a significant positive effect on achievement," (p.3) while Kirkpatrick and Cuban (1998) conclude that "on the basis of the critical reviews we are unable to ascertain whether computers in classrooms have in fact been or will be the boon they have promised to be" (p.6). More often than not, individual studies do find that computer use leads to outcome improvements, supporting Sivin-Kachala and Bialo's optimistic statement; however, concerns regarding the quality and relevance of these studies explain Kirkpatrick and Cuban's hesitance to accept that large positive effects truly exist. We return to these concerns after a discussion of the estimated overall magnitude of effects.

Much of the positive evidence supporting computers' effectiveness comes from meta-analyses. Meta-analysis, or the statistical study of studies, aggregates the findings from multiple studies into a single estimate of effectiveness. Meta-analyses examine the results of multiple studies to estimate an average effectiveness of computer use. To compare studies that use different measures of student outcomes (for example, different states' standardized tests), estimates of the absolute impact on achievement are converted into a uniform measure of "effect size." Effect sizes are calculated by taking the difference in the achievement gains of experimental and control group students (i.e., students receiving computer-based instruction and those receiving traditional instruction) and then dividing this difference by the standard deviation of the measured outcome change. Intuitively, the effect size measures

16 See, for example, critical reviews by Kirkpatrick and Cuban (1998) and Krendl and Clark (1994) and annual comprehensive reviews conducted by the Software Information Industry Association.

the impact of computer usage relative to other factors that cause student achievement levels to vary.

Several meta-analyses have found positive effects of computers on learning. Kulik (1994) reviews twelve meta-analyses conducted from 1983 to 1991 and reports effect sizes ranging from .22 to .57 (p.11). Computer applications with effect sizes in this range would raise a child performing at the 50th percentile level to the 59th to 72nd percentile. In addition, students' attitudes towards computers and their classes are shown to improve with access to computers (p.11). Positive effect sizes within this range are also found in more recent meta-analyses studying the effects of computer use on cognitive outcomes (Liao, 1992), of word-processor use on writing instruction (Bangert-Drowns, 1993) and of computer-assisted instruction (Fletcher-Flinn and Gravatt, 1995).

In addition to the focused individual studies, two large programs are especially noteworthy: the Apple Classrooms of Tomorrow and the Buddy System Project in Indiana. Both programs integrated computer use into both the school and home learning environments.

The Apple Classrooms of Tomorrow (ACOT) studies provided children and teachers with individual computers both at school and at home (Baker, Gearhart and Herman, 1993). The program also provided teacher training encouraging use of the computers for "instructional innovation, emphasizing ... the potential of computers to support student initiative, long-term projects, access to multiple resources, cooperative learning, and instructional guidance rather than stand-up teaching" (Baker, et al., 1993. 2). Despite this intense application of resources, improvement in standardized test scores was comparable to national norms.

Similar to the ACOT studies, the Buddy System Project was an Indiana state program that introduced computer intensive curriculum into the classroom and provided home computers to children in test schools. Miller and McInerney (1994-5) compared school-wide test score gains in a Buddy System school to changes in a school with similar characteristics. The authors also examined achievement gains by sub-categories of gender, academic aptitude, socio-economic status, and the length of time that the program had been in place. In the few comparisons in which the schools had statistically significant differences, the comparison group actually outperformed the group with computers. These results mirror the findings of the ACOT program.

The ACOT and Buddy programs both highlight questions about the appropriate control groups for such studies. Because the programs were accompanied by extensive training, the effects of computer use might be confused with the effects of teacher training. An appropriate control group, therefore, would have participated in a program with a similar level of teacher support but without increased computer usage. The two programs also combine the effects of home and school-based technology use. To separate the effects of computer use at school from increased use at home, researchers need a control group that is provided with similar at-home access, but no new school-based access.

DIFFERENCES ACROSS SUB-GROUPS

As in the Buddy Program, many studies examine sub-groups separately to learn if computers affect children differently based on their gender, ethnicity or socio-economic status. The general sense in the literature is that computer learning tools can be particularly effective for the educationally disadvantaged. For example, in Bangert-Downs (1993) meta-analysis of word-processor use and writing instruction, the average effect size for the 9 studies that targeted students with weak writing skills was .49, much higher than the average effect size over all studies. Kirkpatrick and Cuban (1998) note that "a plethora of reports on at-risk student use of technologies in classrooms boast positive results, but few rigorous studies have examined this population" (p. 3).

Swan, Guerrero, Mitrani and Schoener (1990) focus on the educationally disadvantaged in their study of 13 different computer-based instruction programs implemented across 26 schools in New York City. The study found statistically significant improvements in standardized reading and math tests for program participants. Improvement tended to be highest for lower grade levels and for lower performing students. This differential improvement may be driven by smaller than average class sizes in program classes. Another weakness of the study is that effects were measured by the difference between pre- and post-program scores, rather than the difference in gains between students in and not in the program. If there is a regression toward the mean in test scores, the differential effect by ability level could be an artifact of the tendency for the highest and lowest achievers in any given year to move back towards average achievement levels in the following year. For example, higher performing students might be less challenged, and realize smaller achievement gains, while lower performing students work to "catch-up."

Further evidence that lower achieving students benefit more from access to computers is found in West Virginia Basic Skills/Computer Education (BS/CE) program study. Differences in the access to elements of the (BS/CE) program were more strongly correlated with tests score gains for students with low grades (C's) than for students with high grades (A's). The authors hypothesize that students without access to other educational resources are more sensitive to program resources.

In most of these studies the focus of the computer intervention is on basic skills development. It makes intuitive sense that lower ability students would benefit more from these programs. It is quite possible, though, that other programs would have the opposite bias, disproportionately benefiting high ability students.

CRITIQUES

Education researchers have several concerns with these studies that mitigate the generally positive view of this literature. To begin, many studies are fundamentally limited in their relevance due to inadequate sample size. Insufficient study length is also an issue as short-term studies may actually measure "students' responses to the novelty of using computers rather than to the instructional potential of the delivery system" (Krendl and Clark, 1994. 90). Other key issues include the failure to adequately control for other elements in the student environment that affect outcomes and a general reliance on standardized test scores as a measure of achievement gains.

In general, the failure to control completely for other educational components may lead researchers to attribute to computer use gains that are actually generated by superior teaching or other inputs. Kirkpatrick and Cuban (1998) review evidence that the failure to account for the role of individual teachers may lead to an overestimation of computers' effects. Many studies lack a true control group and simply compare students' pre- and post-program outcomes. This approach attributes all outcome gains to the computer application even though some improvement would have been expected without a special program intervention, especially when the computer educational tool is accompanied by extensive training of teachers and involvement of researchers in educational activities in the classroom.

Another major shortcoming is "the typical reliance on achievement test scores as the sole indicator of instructional effectiveness" (Krendl and Clark, 1994, p. 88). This reliance is understandable given the difficulty in measuring other criteria such as problem-solving skills, or the ability to synthesize information. Nevertheless, these studies tell us little about the effect of computer use on many educational outcomes of interest.

The most fundamental concern in examining studies of specific programs is their dissimilarity from the common ways in which computers actually are used. If computers are typically used in very different ways than they are in a given study, evaluation of that program will have little to tell us about the overall effect that computers have on children's outcomes in all school settings. The next section will review studies of computers as they are typically used.

IMPLEMENTATION AND ACCESS METHODS

Knowledge about typical computer use is needed to evaluate investments in technology that will increase access without changing the nature of usage. Differences in implementation across groups are also key to the ultimate effect of computer use on achievement dispersion.

The evidence on the general usefulness of computers in education tends to come from statistical rather than experimental studies. The former studies use regression analysis to create statistical controls for non-computer related differences in schools and students that affect outcomes. These controls are used to separate the causal effect of computers from other factors that could generate a correlation between outcomes and computer use. For example, another causal factor, like student motivation, may lead to higher levels of computer use and higher achievement. If we do not account for this third factor, its causal effect on achievement could erroneously be attributed to computer use. The more other factors affecting computer use are controlled for, the closer we can estimate computers' causal effect.

Wenglinsky (1998) analyzes data on computer use and test scores from the 1996 National Assessment of Educational Progress. The paper relates math scores to four measures of computer use: "frequency of school use for mathematical tasks, access to home computers/frequency of home computer use, professional development of mathematics teachers in technology use, [and] higher order and lower-order uses of computers by mathematics teachers and their students" (25). Even after taking into account measures of family and school characteristics, several interesting correlations remain. Frequency of computer use at school and at home is related to lower outcomes for fourth graders. Home use is positively related to math scores for eighth graders, and having a teacher trained with computers is related to higher scores for both grade levels. The use of computers for high-level skill instruction is also related to higher scores, while use of drills as the primary application is negatively related to outcomes. These findings imply that in some cases increasing raw access to computers can actually depress student achievement. Well-trained teachers and sophisticated applications are required to make computer use productive.

Family and school characteristics, which are not measured completely and precisely, also are correlated with computer use, so that the relationship between computer use and outcomes may be caused by other inputs that are related to both outcomes and computer use in ways that can not easily be accounted for in statistical models. Specifically, differential access related to student characteristics may be driving the observed correlations. If student and school characteristics are measured imprecisely, the level of access may actually act as a substitute measure of school quality and child's expected performance. Since "at-risk" populations seem to have greater raw access to computers, simple frequency measures could be correlated with negative outcomes because frequency of use is higher for children that would otherwise be expected to perform poorly.

Angrist and Lavy (1999), study data on computer use in Israel to estimate the effect of computer assisted instruction (CAI) on children's performance on standardized math and verbal tests. The most robust result in this study is a general inability to find a significant effect of CAI intensity on test scores. Similar to Wenglinsky (1998), the few significant results relate CAI intensity to lower test scores.

As with Wenglinsky (1998) unobserved differences between schools with high and low CAI intensity may drive differences in student scores. The authors attempt to control for this with the inclusion of available student and school characteristics, but some contamination may remain. Nevertheless, the conclusion of this analysis is that increased computer use does not have a positive effect on student achievement.

Mann, et al. (1999) study data from West Virginia's Basic Skills/Computer Education (BS/CE) program. BS/CE is a statewide program that provided each elementary school with three to four computers per classroom starting in 1990-91 (the investment was phased in, at one-grade level per year). Mann, et al., regress student test scores on nine program elements including measures of computer use, student attitudes and teacher training. Increases in these elements are correlated with increased test-scores. The study does not include any school or individual characteristics so that these regression coefficients are likely to be biased by the effects of these omitted factors.

None of these three studies yields strong evidence that school-based computer use increases basic student skills. The ACOT and Buddy System programs show no significant positive effect on student scores and the West Virginia BS/CE program does not allow statements regarding the causal effect of computers on student learning.

THE RELATIONSHIP BETWEEN FAMILY CHARACTERISTICS AND IMPLEMENTATION

Wenglinsky (1998) and Angrist and Lavy (1999) suggest that simple access to computers may not increase outcomes. The exact nature of computer use is likely to be more important than the simple presence of computers in school labs. While access is relatively equalized across student groups, there is evidence that use and teacher support varies with student characteristics.

Wenglinsky (1998) presents data on patterns of technology use by different student groups. In the 1996 National Assessment of Educational Progress, disadvantaged groups had equal or greater access to computers as measured by frequency of use; however, students from disadvantaged groups tended to have lower access to well-trained teachers and used computers in less sophisticated applications. The causal relationship between student outcomes and different measures of computer use is not entirely clear, but disadvantaged students seem to still lack equal access to the factors that are likely to make computer use productive.

Similar patterns are found in other reports on student access by ethnicity and income. Krendl and Clark (1994) review earlier figures showing that students in schools with high-SES student-bodies tended to have higher computer to pupil ratios. They also cite reports by Becker (1986) that low-income and minority students were more likely to use computers in applications with lower sophistication, "drill and practice" versus "exploratory computer activities" (p. 97). Becker (1994) reports that computer density in schools had almost been equalized across ethnic groups except for Hispanic students and students in schools that are "nearly all-minority." He also reports evidence that children from high SES families, as well as children attending schools whose student body tends to come from families with high SES, are more likely to use computers in "higher-order" activities. Although low-SES background is related to more frequent low-order use Becker finds that "low school grades are more consistently related to low levels of computer use than is coming from a low-SES background" (section 8).

These studies paint a fairly consistent picture. Early disparities in access to computer technology as measured by computer density, or the ratio of students to computers, have largely been remedied. Differences in teacher training and the ways in which computers are used by students are still related to student race and income level. These differences in access to and use of computers in schools will tend to increase the achievement gap.

IN-HOME COMPUTER USE

The importance of family and home inputs into children's academic success suggests that home computer use may have an equal or even larger effect on children's outcomes than school-based use. Home access has received much less study than school-based use. This may be because "experiments" introducing computers into homes are more intrusive and expensive than programs that alter computer use at school. Nonetheless there are some studies into the effect of home-based computer use.

Although there have been studies providing students with home access to computers, these programs have not focused on specific applications in the same way that school-based experimental programs have and most of the evidence on home access is, by default, evidence on the effects of home computers as they are typically used.

EXPERIMENTAL EVIDENCE

Simple correlations between home computer use and educational success largely reflect the effect on achievement of coming from the type of family that is likely to own a computer (higher income, higher SES and parental education, and disproportionately white). One way to find the direct causal effect of access to a home computer is to measure the impact of an experiment that randomly distributed computers to students for home-use. Both the Apple Computers of Tomorrow and Buddy System provided students in program schools with computers for home use. The programs also increased classroom computer use, provided teacher training and encouraged curriculum redesign. In the two programs, the effect of additional home computer access cannot be isolated from these other factors.

Other experimental evaluations of home computer use, as reviewed in Attewell and Battle (1999), have been unable to demonstrate general positive effects of home ownership; "home-computer users as a whole have not out-performed matched control groups" (p. 1). The results of these studies are similar in flavor to the evidence that increased school computer density does not in and of itself lead to improved student outcomes.

STATISTICAL EVIDENCE

In addition to the experimental evidence, there is some statistical evidence on the effect of home computer access. Attewell and Battle (1999) analyze data in the 1988 National Educational Longitudinal Study on the presence of computers in the home and on student outcomes. Home computer use is positively related to standardized test scores and to self-reported grades even after taking into account several key demographic and individual characteristics. On average, students with home computers scored 3 percent to 5 percent higher than students without computers.

In addition to direct effects of home computer use, home access may affect students' in-school use and attitudes towards computers. Selwyn (1998) finds a positive relationship between home use and sophisticated in-school use (programming, simulations, e-mail and Internet) as well as on attitudes towards computers. This study does not control for student socioeconomic status, but still highlights a potentially important interaction between home access and school use.

THE EFFECTS OF FAMILY CHARACTERISTICS ON EFFECTIVENESS

Differences in in-home access to computers are much greater than differences in school based access. As documented earlier in this report, Black and Hispanic families are less likely to have home access than are white and Asian students. Poorer families and families in which parental education is lower are also less likely to own computers. Even more important may be the way in which computer use varies across these groups. Attewell and Battle (1999) investigate the effects of home use by sub-groups. They find that female, Black and Hispanic students received less of a benefit from home computer use than did male students and white students. Low SES students also received less value from home computer use than did high SES children. The authors cite Giacquinta, Bauer and Levin's (1993) finding that the bulk of children's at-home computer use is non-educational. They hypothesize that parental intervention is required to make computers effective learning tools. Families with higher socioeconomic status may be better able to encourage educationally productive computer use. Similarly, female children may receive less in-home encouragement in computer use. Race may also be linked to the nature of in-home use though the authors have no evidence on differences in use across racial groups.

Computer use also may vary with the idiosyncratic value that parents place on education. Parents who are already more involved in their children's education will be more likely to encourage productive home computer use. This will tend to exacerbate differences in student achievement since those students with high levels of in-home support will also receive greater benefits from computer use.

Similar to the evidence regarding school-based use, simple measures of access to computers may miss important differences in the ways that children use computers. The same factors that affect the distribution of traditional educational inputs will also affect the likelihood that computers are put to educationally relevant use.

OVERALL ASSESSMENT

The research to date on the educational effects of computer use is far from clear and complete. Certainly in some cases students are significantly benefited by both in-class and in-home computer use. There is good evidence that specific computer applications can increase student outcomes. There is also some evidence that benefits can be greater for lower achieving students, tending to decrease the gap in student outcomes. But these effects appear to depend strongly on both the total school and home environment of the student. And, other evidence indicates that higher socioeconomic status students thus far have derived more benefit from educational uses of IT.

One should not conclude from these studies that computers are likely to make the digital divide even worse, even if all students are given access to both computers and good educational software. But studies to date do indicate that computers are much like educational advances of the past: without parallel activities to cope with other disadvantages and to improve teacher training, as well as the entire school environment, computers are not likely to have much of an effect on the educational achievement of disadvantaged children.

It is not clear from the research to date that the potential achievement gains from computer use are worth the expenditures. A few studies have estimated the relative cost-effectiveness of computers as educational tools (Krendl and Clark, 1994, p.89). These studies suggest that spending on teacher education or the purchase of other resources would lead to greater gains than equal spending on educational IT.

Even if optimally implemented programs are cost-effective, current research shows little evidence that typical usage has significant benefits. This may be due to a disconnect between raw access and productive use. Becker (2000) finds that students are more likely to actually use computers when they are located in the classroom, rather than a lab. Teacher training and philosophy also affect the frequency of student use. These findings suggest that locating computers within the class may be more useful than grouping them in a lab, even if there are not enough computers to equip all grades. These results also highlight the broadly accepted finding that teacher training is key to effective use (Wenglinsky (1998), Shaw, et al. (1997)).

While school-based access is high for students of different ethnic and income groups, there are still disparities in teacher training levels, the ways in which computers are used by students, home access to computers, and parental computer skills. Parental and teacher support influences the benefits that children get from computer use. Computers may be important learning tools, but their value is not accessed simply by placing them in schools. Computers affect children's educational performance as part of a larger system of inputs. Programs that recognize the importance of this existing structure will be better able to extract the potential benefits of the computers.

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Appendix

Study/Program	Design	Size	Effect[17]	Notes
Kulik (1994) Review of 12 Meta-Analyses and further analysis of 97 studies.	Paper first reviews findings from 12 meta-analyses. Studies are then grouped into various categories in an attempt to increase the consistency of results. The first level includes all studies. The second level splits studies into usage groups. The third level looks only at studies of the Stanford-CCC program.	Level 1: 97 studies	Average Effect Size (Standard Dev.) .32 (.39)	All studies included a control group that is taught without computer based instruction.
		Level 2 studies: Tutoring - 58 Managing - 10 Simulation - 6 Enrichment - 5 Programming - 9 Logo - 9	 .38 (.34) .14 (.28) .10 (.34) .14 (.35) .09 (.38) .58 (.56)	
		Level 3: 13 studies	.40 (.23)	
Bangert-Drowns (1993) Meta-analysis of writing instruction using word processors.	All studies examine 2 groups. Treatment groups use word-processors during instruction. Control groups are almost always in the same schools and other learning conditions are the same.	33 independent studies. 28 studies report measure of overall quality	Effect on the overall quality of writing. Overall effect sizes Mean: .27 Effect sizes for remedial writers: Mean:.49	Evaluation conditions (by hand versus by computer) differed in nine of the studies. The paper also reports results for writing quantity, revision frequency, and attitudes towards writing.
Liao (1992) Meta-analysis of studies on the effect of computer use on cognitive outcomes.	Studies examined differences in cognitive outcomes measures for groups receiving instruction with and without computers. Measures were generally scores on tests of cognitive ability.	31 studies yielding 207 comparisons. Sub-group comparisons are weighted by 1 over the number of subgroups in the study.	Effect Size Mean: .48 Median: .34	For inclusion, studies were required to have a control group that received instruction without a computer.

16 Effect sizes represent the standard deviation increase in the outcome measure attributed to program participation.

Appendix

Study/Program	Design	Size	Effect[18]	Notes
Fletcher-Flinn and Gravatt (1995)	Meta-analysis of computer assisted instruction studies conducted between 1987 and 1992	120 studies	Overall effect size: .24 Average effect size in later studies (conducted from 1989-1992): .33	Later studies were examined separately and found to have higher effect sizes even after taking program implementation length and other design factors.
Baker (1993) Apple Classrooms of Tomorrow, UCLA Evaluation Studies.	Children and teachers were provided with individual computers at school and home. Teachers were trained in computer integrated, project-based curriculum.	5 separate school sites.	Performance on standardized tests of basic skills was comparable to national norms.	Program students were compared to national standards and comparison classrooms. Implementation differed across sites. Treatment included significant teacher training as well as computer access.
Miller (1994-5) Buddy System Project.	Indiana program provides 4th-5th graders with home-computers and technology focused class room instruction.	142 students in the 4th and 5th grades from 1988-1992. All students were from a single Buddy Program school.	The comparison group scored significantly higher on standardized tests of reading, language and mathematics (the California Achievement Test and the Comprehensive Test of Basic Skills, 4th ed.).	The participating school was compared to a similar school in the same district with a computer lab, but less focus on technology in the curriculum. About 1/3 of these students already had home computers.
Wenglinsky (1998) Statistical Analysis of the 1996 National Assessment of Educational Progress (NAEP).	Paper analyzes math scores from biannual testing of a national sample of students. Survey data also includes information from students, teachers and principals surveys.	6,227 Fourth-Graders 7,146 Eighth-Graders	Estimated fraction of a grade level advantage enjoyed by students with the characteristic. 4th / 8th Graders School Use: -.20/-.11 Home Use: -.26/+.14 Teacher Training: .09/.35	Regressions include measures of student SES, class size, teacher traits and other school traits. The negative effect of computers on outcomes may be due to an underlying positive correlation between educationally disadvantaged student bodies and computer access.

18 Effect sizes represent the standard deviation increase in the outcome measure attributed to program participation.

Appendix

Study/Program	Design	Size	Effect[19]	Notes
Mann, Shakeshaft, Becker, and Kottkamp West Virginia Basic Skills/Computer Education program.	State program funds computer purchases sufficient to supply 3-4 computers per class in a targeted grade. The program was phased in one grade per year starting with the 1990-91 kindergarten class.	The entire state of West Virginia.	Standard deviation increases in outcome per unit increase in element. Time spent using comp.: .089 Software access: .367 Computer access:.068 Other tech. access: .051 Student attitude re. computers: .169 Teacher attitudes re. computers: .066 Teacher confidence: .030 Teacher involvement: -.097 Teacher training: .095	Effect measures are not comparable to each other or usual "effect sizes" since they are sensitive to units of individual elements. There are no controls for student and school characteristics other than those measured as a part of the program.
Swan, Guerrero, Mitriani, and Schoener (1990) Computer Pilot Program. Division of Computer Information Services, New York City Board of Education.	Study tracked improvement in test scores for students in 13 separate computer based instruction programs across 26 N.Y. City schools.	26 schools. 1,734 students, reading program. 1,351 students, mathematics.	Overall Effect Size on test scores (Degrees of Reading Power and Metropolitan Achievement Test.) Reading = .8; Mathematics = .9	There is no real control group; 1988 scores are compared to 1987 scores. Programs focused on basic-skills instruction rather than integrated learning. Teacher-student ratios were far below NY average. In general, improvement was inversely related to grade and prior ability level.

19 Effect sizes represent the standard deviation increase in the outcome measure attributed to program participation.

Appendix

Study/Program	Design	Size	Effect[20]	Notes
Angrist and Lavy (1999) Israel's Tomorrow-98 program.	Lottery proceeds were used to fund computer purchases by selected state schools.	905 schools received funding from 1994-1996. Data is from national sample of student test scores and characteristics.	Regression coefficients on intensity of computer use are insignificant or negative, ranging from -2.71 to -8.65. A one unit increase in CAI intensity (on a scale of 0 to 3) is estimated to lead to a -2.71 to -8.65 point decline in test scores (ave. scores lie between 57 and 69 points).	Program funding was distributed based on student need and school's ability to use the funds. This may negatively bias coefficients.
Attewell and Battle (1999) Analysis of NELS88 (National Educational Longitudinal Study 1988)	Analysis of survey data on home computer use and standardized tests in reading and mathematics, and students' self-reported grades.	Nationally representative sample of approximately 18,000 8th graders.	Standard deviation increase in outcome associated with standard deviation increase in home computer presence. Overall: .04 to .07 By subgroup: SES: .00 to .03 Gender: -.02 to -.04 Black: -.01 to -.02 Hispanic: -.02 to -.03 Native American and Asian: not significant	Regression includes controls for socioeconomic status, region, urbanization, gender, ethnicity, family structure and size, measures of parental involvement with children and of "cultural capital."

20 Effect sizes represent the standard deviation increase in the outcome measure attributed to program participation.

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As we approach the Christmas season, an economist who participates in a program of this nature is inevitably made to feel like Scrooge. It is not that all arguments about "universal service" or "equal access" are simply "humbug." Rather, it is important to warn about the dangers inherent in interfering with consumers' rights to direct the allocation of their scarce resources and choose their own consumption baskets. Clearly, everyone should have access to important new services, but should this access not be priced to reflect the cost of delivering it? Equal access or universal service - perhaps to span the "digital divide" — carries a price that consumers can choose to pay. If they choose not to avail themselves of a new, meritorious service at such a price, when should we decide collectively to allocate this service to them regardless of its cost or at least provide a subsidy to induce them to change their minds?

It is not sufficient to argue for such intervention on the basis of income distribution. If we are simply concerned that some households cannot afford some of the luxuries of the new millennium, the solution lies in some form of direct income redistribution, not in subsidies to new digital services. If, however, we think that others, including ourselves, benefit from another household joining the digital world, a case can be made for offering this subscription at a price that is less than its cost. However, such a policy may require an increase in the price of something else in order to pay for it. The lesson from existing subsidy programs is that these costs can rise to very large levels even after we discover that they are no longer necessary to achieve universal use of the service. For this reason, I begin with a brief review of the history of universal-service subsidies in telecommunications, a history that should be sobering to all of us as we sift among current policy choices.

WHAT MAKES COMMUNICATIONS SERVICES UNIQUE?

Presumably, there is something different about communications services that commands our attention this morning. At one time, we might have distinguished telecommunications from other goods and services on the basis of supply conditions — they were offered by large, monopolistic firms. But today, there are scores of firms competing with one another for my business. I brought my telephone with me, and I am sure that I could even switch suppliers somewhere in Palo Alto during our lunch break today. Residents in a number of cities are now even being offered wireless services with unlimited usage for $30 per month, providing wireless competition for the traditional local wireline carriers. The monopoly appears to be disappearing.

Turning to the consumer demand side of the market, we might once have been concerned because of the cost of basic telephone services was prohibitive for lower-income households. But surely this is no longer a problem — basic local telephone services absorb less than 2 percent of the budgets of even the lowest-income U.S. households and this share will fall as innovation reduces the price of wireless and wireline telephone service alike.[1]

1 These data are drawn from Robert W. Crandall and Leonard Waverman, Who Pays for Universal Service? When Telephone Subsidies Become Transparent., Brookings, 2000.

A more important demand consideration is that, unlike most other goods and services, one person's consumption of telecommunications may generate benefits to others that cost the latter nothing. When you subscribe to the telephone network, I benefit from being able to call you. Therefore, I can make a case for providing you incentives to subscribe or to call me, over and above the incentives provided by the market, unless you would subscribe or call me anyway. But surely I would not make the same argument for all subscribers - including, say, telemarketers. Clearly, I do not feel compelled to subsidize everyone's use of the network or even to subsidize your connection or call if you already find that the value of the connection exceeds its cost.

Today, 94 percent of all households have access to basic telecommunications services from their homes. Perhaps another 1 percent or more are in the process of moving. Others choose to avoid having a fixed telephone line and to buy a cell phone instead. Finally, a few do not have telephone service because of past failures to pay large long-distance bills. Very, very few households are rationed out of having a telephone in their homes by its current price, which is about $13 per month for a low-income family. Given the very low price-sensitivity of demand, very few would chose to exist without a telephone even if the price were $30 or $40 per month for a connection. The demand for connecting to the network is extremely price insensitive. In the jargon of today's policy discussion, we have "universal service" in ordinary analog telephony and would undoubtedly have it with or without universal service policies.[2]

THE HISTORY OF UNIVERSAL SERVICE POLICIES

Early in the 20th century, after the Bell patent monopoly had expired, perhaps 20 to 25 percent of households had a telephone. New entrants into local telephone service were everywhere. It was at this time that the term "universal service" was invented by AT&T. The company's objective was to promote a government policy encouraging all of these households to connect to one network, namely, AT&T's network rather than that of a competitor.

The term took on a new meaning in the 1970s when AT&T was once again under threat from competitors. Universal service was now redefined as the assurance that all households — rich and poor; urban and rural — be granted monthly telephone service at "affordable rates," often below the cost of providing the connection. Since this policy required that AT&T be allowed to continue charging far more than cost for other services, namely, long distance services, AT&T was throwing down the gauntlet. Allow competition in long distance services and the source of these subsidies would dry up, requiring the company to raise local monthly rates for connecting to the network. This ex post defense of a distorted rate structure subsequently became enshrined in a policy of "affordable" local rates that permit everyone to have telephone service even if these low rates are not a necessary condition for assuring universal service.

As we know AT&T eventually lost its battle against the entry of new long distance carriers, but the regulators' universal service policies remained. Today, 30 years later, we still have regulators keeping local monthly residential rates artificially low in the name of universal service and paying for this policy by taxing other services — particularly long distance service. Local rates are kept far below cost in rural areas for rich and poor alike. Ironically,

2 Differences exist among income levels and demographic groups. However, virtually all U.S. households with incomes above $10,000 per year now have telephone service.

this policy has punished the development of the Internet in rural areas because it increases the cost of connecting to the Internet for those who must do so through intrastate long-distance service.

These traditional universal service policies are not only unnecessary because very few people would disconnect from the network if they had to pay the true cost of their service, but they are very costly because they reduce the number of calls made by consumers. The value of these lost calls is surely in excess of $5 billion per year and probably much more because without this policy we might today be paying 2 or 3 cents per minute for calls to anywhere in the country — or to anywhere in the world if other governments would abandon similar policies.

Most of our regulators now recognize the folly of universal service policy for traditional telephone services, but they are wed to them by the necessities of politics. Because long-distance calling is highly skewed, with a small share of households making a large share of the calls, the cost of the current policy is borne by a minority of households in the form of high long-distance prices for calls to friends, relatives, and even the Internet. The median household — and the median voter — benefits from this policy because it makes a relatively small number of long distance calls, but receives its local service at artificially depressed rates, particularly if it is located in a rural area.

The losers from this policy are those who use long-distance services intensively, and they could easily compensate the winners and have $5 billion or more per year left over. Unfortunately, the regulators have no simple way to effect this transfer. The result: a wasteful policy that induces us to under-use the network and one that endures even when there is clearly no case for continuing it. One should keep this in mind when thinking about new subsidy programs — they are likely to be costly, difficult to change and outlast the policy rationale for them.

Nor is this policy simply a matter of taxing the rich callers to pay for poor households' connections to the network. In all income classes, long-distance calling is highly skewed. Twenty percent of households earning less than $10,000 per year spend more in a given month on long-distance service than do 60 percent of those making more than $75,000 per year.[3] Calling is income sensitive on average, but it is very unequally distributed in each and every income class because of differences in the age composition of households, social networks, family needs, or perhaps even loquacity. By the same token, the beneficiaries of the depressed rates for connecting to the network — i.e., lower monthly flat rates for local service — are both rich and poor because the degree to which these rates are depressed varies inversely with population density. Rich and poor alike benefit from these lower rates because both are found in rural areas, some toiling in the fields and others on the ski slopes. Thus, one cannot defend the current universal service policy as an efficient mechanism for creating a more equitable distribution of income.

There is a further lesson to be derived from an economic analysis of traditional universal service policies that is extremely useful when considering policy options for the new digital world. Even if keeping local telephone rates low in rural areas or for lower income households in any area of the country were defensible as a policy goal, such a policy would be less burdensome if its costs were borne by general tax revenues, not by long-distance services. The current policy not only buries the cost of the subsidy from view in the form of

3 Crandall and Waverman (2000), Table 3-1.

elevated long distance rates (and rates for other telephone services), but it places the burden entirely on these latter services. A general tax on all income or consumption is likely to be far less burdensome — in terms of valuable foregone economic output — than a tax on a small set of regulated services. This is particularly true if the tax is on services that are much more price elastic in demand than is the service being subsidized.

TELECOMMUNICATIONS POLICY IN OUR FEDERAL SYSTEM OF GOVERNMENT

One might reasonably ask why we continue a policy of universal service subsidies for local telephone service given that it is unnecessary and so inefficient. The answer is rooted in the politics of appealing to the median voter, as I pointed out earlier, and in the power of rural states' congressional delegations.

The current policy redistributes income from urbanized states to rural states through direct subsidies and through the implicit subsidies paid through interstate long distance calls. Were the current rural subsidies in each state paid entirely by the residents of that state, the current local rate structures in states such as Wyoming and Mississippi would require regulators to place a tax of 40 percent or more on intrastate long distance services.[4] Clearly, it is better for these states to ask their Congressmen, and especially their Senators, to continue the federal universal-service program. It is no accident that the Senate oversight committee for the Federal Communications Commission has been dominated by Senators from Alaska, South Dakota, and other rural states and is often referred to as the "farm team."

UNIVERSAL ACCESS FOR NEW SERVICES

We are not here today to discuss past regulatory error, but to engage in a discussion of how to provide wide access to the wonderful new world that the electronics revolution is opening up to us. The startling decline in the price of computers, fiber optics, and switching devices is allowing most, but not all of us to be in touch with the world in a manner that Jules Verne, George Orwell, or even George Gilder could never have imagined. As these services proliferate, higher income households are most likely to be the first to try them. This is particularly true if such services — like the Internet — also have professional or business applications that are more likely to be first used by persons of higher than average income.

When these new services are initially being deployed, there may be substantial "consumption externalities" that I discussed earlier that are not being exploited. In such a circumstance, it is rather seductive to propose some form of subsidy to hasten the rapid diffusion of these new services. Such a proposal has particular appeal if these services are likely to be more expensive and inaccessible to poor households, creating further possible justification for subsidies. For instance, a 1995 RAND study suggested some such program for a new service — e-mail.

But the economist in me resists many prescriptions for government intervention. How do we know what to subsidize? Will today's candidate turn out to be CB radio? Or will it be the Internet? If it is the Internet, we might be misled into providing subsidies for ISP connections at a time when ISPs are being overtaken by new organizations that manipulate and distribute content. Surely the billions of dollars that we pay to subsidize paired copper-wire telephony

4 Id, Chapter 7.

in extremely rural areas is now questionable on simple cost grounds given recent developments in wireless telephony. But do you think that Vodafone/AirTouch will qualify any time soon for such subsidies when small, rural telephone "co-operatives" survive only because they are uniquely eligible for "high-cost" support?

The irony that surfaces in examining the case for government promotion of new telecom services is that such a policy is dangerous in the early stages of development of a new service - because it might target the wrong service — and largely unnecessary when the universal need for the service has been demonstrated in the marketplace. We might have made a case for subsidizing personal computers and the Internet to capture the externalities from more rapid diffusion of the Internet six or seven years ago when few of us could see where this technology was taking us. Today, however, a rudimentary PC costs about as much as a color television and an Internet connection costs somewhere between zero and one-half the cost of a cable television subscription. Everyone has a color TV (or two or three) and 70 percent of households have cable television. Universal television is here, and universal Internet service appears to be on the way without direct government subsidies.

The latest data from the Department of Commerce show that 51 percent of households had a personal computer by August 2000, an increase of nearly nine percentage points since December 1998. During this period, the share of households with Internet access soared from 26.2 percent to 41.5 percent.[5] A recent large private household survey shows even greater household participation. It finds that 60 percent of households have a PC and that 51 percent are connected to the Internet.[6]

But if Internet services arguably no longer need our attention because they are affordable and are rapidly becoming universal, how about high-speed Internet services? Today, no more than 4 percent of all households subscribe to a high-speed Internet access service. Obviously, this is far from "universal" coverage and for good reason. The price of one of these services is generally more than double the price of a standard telephone connection. Is it worth this much to many households? Will large numbers of other households subscribe? The answer is that we simply do not know because no one can predict how these services will be used and whether the value of high speed is greater than or equal to $480 per year for most households, the current average price for digital modems or DSL service. At present, fewer than 5 million households have such a service, and many have difficulty making the service perform as promised.

The frequently expressed concern about the "digital divide" is, in reality, simply an observation that higher-income households are early adopters of the newest technology, whether it is a fad or not. Ironically, given the incredible rate of technical progress in all things digital, once we understand that a new service or device is very valuable to all households, it is likely that virtually all will be able to afford it and will have it.

It is unlikely that many households will avail themselves of a subsidized service if this service has little value to them. On the other hand, they will gladly accept the subsidy for a service that they would have purchased at higher, market prices anyway and that they will support the continuation of such a program, much as rural households insist on a continuation of below-cost, "affordable" local telephone service. Owners of ski

5 U.S. Department of Commerce, National Telecommunications and Information Administration, Falling Through the Net: Toward Digital Inclusion, October 2000.

6 TNS Request Market Monitor, Jenkintown, PA, Second Quarter, 2000.

condominiums and rural vacation retreats begin to view low-cost telephone service as a right even if it is subsidized largely by households with lower incomes than theirs.

In short, there is a substantial risk that an unnecessary subsidy for the newest digital technology or service will become permanent. Assume, for example, that we design a policy to subsidize household personal computers and Internet service that covers about one-third of the cost of this package for consumers at current prices — a share roughly equal to the low-income subsidies currently available for local telephone service. This might total at least $125 per year for each eligible household.[7] If 5 to 10 million households availed themselves of this subsidy, the annual cost would be $625 million to $1.25 billion per year. Even if the PC/Internet combination spread to 90 percent of all households, there is no reason to believe that the population eligible for the subsidy, PC manufacturers, or ISPs would agree to let the program lapse. If we were then to extend this subsidy to one-third of the price of DSL or cable modem service, another $800 million to $1.6 billion per year could become similarly politically untouchable.

THE E-RATE PROGRAM FOR SCHOOLS, LIBRARIES, AND RURAL HEALTH FACILITIES

The cost of new PC/Internet subsidies may appear small by themselves, particularly when compared with the annual cost of new Medicare prescription-drug programs or a missile defense system, but they add up and create a cumulative burden that must be financed somehow. The federal government has recently adopted a new set of subsidies for Internet connections for schools and libraries and for telecommunications services for rural health facilities that are being paid for by a tax of 2.6 percent on interstate telephone revenues. This is in addition to the direct tax of 3.3 percent for the direct federal "high cost" and "low-income" subsidies for traditional telephone connections that are built into the rate system. Are we to fund new subsidies to overcome today's digital divide in the same manner? If so the cumulative burden could become very large.

Leonard Waverman and I have estimated that the current subsidies for schools, libraries, and health care facilities cost the U.S. economy at least $3 billion per year, or $1 billion more than their direct budget, because of the effects of imposing the 2.6 percent tax on interstate services.[8] Jerry Hausman and Howard Shelanski have estimated the cost to be even higher, about $2.5 billion over and above the program's direct cost of $2 billion.[9] At the very least, in order to keep the economic costs of any new subsidy program as low as possible, the new subsidies should be funded from general revenues, not from higher specific taxes on telecom services.

There is also a practical argument against creating a telecom-based set of subsidies for these institutions. The need for such services surely varies across the eligible institutions. Schools in poor areas may be less able to fund Internet connections because they have tighter budget constraints than those in wealthy areas. But is it good educational policy to require that federal subsidies be dedicated to telecommunications services, inside wiring, or Internet service? Surely, it would be better to let the local school authorities allocate their budgets between teachers, physical facilities, books, and advanced telecommunications as they see fit.

7 This is a conservative assumption. I assume that a computer is purchased for $400 and amortized over two years and that Internet service costs $180 per year.

8 Crandall and Waverman (2000), Ch. 7.

9 Jerry Hausman and Howard Shelanski, "Economic Welfare and Telecommunications Regulation: The E-Rate Policy for Universal Service Subsidies," Yale Journal on Regulation, Vol. 16, pp. 19-51.

To make the current e-rate program more politically attractive, it is designed to provide some benefits even to the wealthiest communities in the United States. This extends not only its political base, but its cost. The result is a program whose cost has become a political issue in the last few years. Were the program more carefully targeted to low-income areas, it would be less controversial, but then it might not attract as broad-based support from educational and public-library organizations.

UNIVERSAL-SERVICE RESPONSIBILITIES FOR TELECOMMUNICATIONS CARRIERS?

A troubling possibility is that new subsidy programs - say, for high-speed Internet connections — might be buried in universal-service obligations for carriers rather than being paid for through an explicit tax on carrier revenues. The common carrier obligation for telephone companies or even cable companies can easily be converted into an obligation to serve all customers at the same price. Indeed, such language is now in the Telecommunications Act for local and long distance telephone service. It would be easy to draft a narrow, technical amendment to the Act that extends this requirement to all advanced telecommunications services. If a carrier offers high-speed DSL service to any households in its franchise area in, say, Utah, it might be required to charge the same price to Salt Lake City residents and to the most remote cranny of the Wasatch Mountains. Obviously, such a requirement would result in rates that are above cost in the urbanized areas and far below cost in remote areas. By now, this should be a familiar story.

But with new, advanced services, there is no guarantee that the carrier will offer them anywhere. Indeed, a literal universal service responsibility for DSL service would be a disaster because the telephone plant in the most rural areas simply cannot deliver the service. The existing telephone networks in these areas would have to be rebuilt at substantial cost just to offer a few households this new service that perhaps even fewer desire anyway. Rather than incurring these costs and suffering a negative return on investment, many carriers would probably chose not to offer the service anywhere.

If such an obligation were placed on telephone carriers, it would be difficult to see how cable television companies could avoid a similar fate. This would generate yet another U-turn in cable television policy, which — thankfully — has moved in the direction of deregulation once again. Previous exercises in regulating cable television have cost consumers dearly in terms of program choices; we would be making a major mistake to submit this industry to detailed regulation once again.[10]

Given the high cost of upgrading rural cable plant and deploying two-way capability, a universal-service requirement for cable-modem service or other advanced services would undoubtedly induce the larger cable television companies to sell their rural operations and concentrate solely on their more urbanized operations. Creating such incentives would clearly be a mistake, adding to the argument against burying a subsidy for new services in "universal service" responsibilities for carriers. Rather, if such subsidies are deemed politically irresistible, they should be carefully targeted to a needy constituency and paid for directly out of general tax revenues.

10 For an estimate of the cost of the most recent exercise in detailed cable regulation, see Robert W. Crandall and Harold Furchtgott-Roth, Cable TV: Regulation or Competition, Brookings, 1996.

BRIDGING THE DIGITAL DIVIDE NATURALLY

It is hardly clear at this point that there is a "digital divide" that needs immediate bridging through a deliberate public policy. As incomes grow and the cost of anything digital falls at a dizzying rate, even the newest digital technology begins spreading across demographic groups. The sharp decline in PC prices and the growing attraction of the Internet have combined to induce an estimated 60 percent of all households to invest in a personal computer by the second quarter of this year.

I have examined the determinants of household PC demand in 1994, just six years ago, and used the results to predict the diffusion of PCs in 1998. Not surprisingly, I found that the 1994 equation substantially under-predicted the diffusion of PCs among poor households and among Black and Hispanic households.[11] The early adopters were skewed towards white, upper-income households, but in just four short years much of this early "divide" was closed by falling prices and lower-income households' discovery of the value of a PC. This gap continued to close in the 1998-2000 period. For instance, the proportion of Black households with a computer rose by more than 40 percent in these two years while the proportion of white households with a computer rose by just 20 percent. Similarly, computer ownership increased much more rapidly in households with less than $10,000 in annual income than in households with $50,000 or more in annual income. A similar trend exists in Internet access across income and demographic groups and in the rural-urban differential in computer ownership or Internet use. In another four years, or in just ten years since the Internet became generally available to households, we may find that more than two-thirds of all families are connected to the Internet at home.

By contrast, 75 years elapsed between the invention of the telephone and its spread to two-thirds of American homes. The "analog divide" was surely much more difficult to bridge than the digital divide. As the prices of PCs, DSLAMs, modems, fiber optics, and switching devices continue to fall, it is not fanciful to predict that current and prospective digital divides will be bridged at an ever faster rate as a result of rising household incomes.

In an environment that is changing so rapidly, it is far from clear that a government policy that would subsidize household connections or devices could be sure of hitting the right target. Today's PC/Internet connection through wires may be supplanted by hand-held devices using satellite circuits or fixed terrestrial wireless services. Even it were justified on grounds of consumption externalities or income distribution, how could the program keep up with these changes? Surely, we do not wish to subsidize everything that evolves from this digital revolution, such as the newest portable game player. And surely we do not want to provide high-income households subsidies for new toys or services that is paid for out of taxes that fall predominantly on households with lower incomes.

The best policy is one that places maximum emphasis on competition to diffuse the very large potential benefits from the electronics revolution. Unfortunately, the old and new universal service obligations on telecommunications carriers have provided substantial obstacles to the development of such competition. The distorted traditional telephone rates that have evolved in the name of traditional universal service have reduced the incentive for new carriers to offer services to residential customers. Most of the new competition unleashed by the 1996 Telecommunications Act has — not surprisingly — been directed at

11 This analysis will appear in Robert W. Crandall, "Bridging the Digital Divide: Naturally, The Brookings Review, 2001.

business customers. Moreover, as long as regulators require some services to be delivered at prices that are below cost, they must try to keep rates for other services above cost and beyond the reach of the new competitors. The perpetuation of the traditional universal service program has reduced the incentives for the older, regulated carriers to move towards "always-on" packet switched connections to their subscribers. It would be far better if regulators allowed all rates to move towards costs and thereby created more competitive opportunities for entrants — including those seeking to deploy advanced technologies to households.

SOME CONCLUDING RECOMMENDATIONS

Current U.S. telecommunications policy places enormous constraints on anyone advocating new policies for bridging the digital divide. Existing subsidy programs place large demands on business and long-distance revenues, particularly in the more rural states. The new e-rate program for schools, libraries, and rural health facilities has added 2.6 percent to federal taxes on telephone services. Given that the explicit federal subsidies for traditional services add another 3.3 percent, it seems unlikely that the political environment would sanction further taxes on interstate telephone service. Attempting to bury a subsidy in a "universal service responsibility" for carriers would not only be an exercise in political concealment, but it could severely reduce the carriers' incentives to roll out the facilities required for these new services.

As a result, it would appear that anyone advocating a new policy for closing the digital divide or otherwise accelerating the diffusion of new services should pursue the following strategy:

- Rely on competition to reduce the market prices of the new services as rapidly as possible;
- Lend support to proposals for phasing out existing rate distortions or subsidy programs that are not justified on grounds of consumption externalities or income distribution;
- Target any support or subsidies to truly needy households, not to the general population;
- Resist saddling carriers with new obligations that reduce their incentives to offer new services;
- Fund any subsidy programs from as wide a tax base as possible, not the narrow base of telecommunications carrier revenues;
- Provide a finite limit on the time period for any subsidy program so as to require frequent legislative reassessments of the need for such a program.

Technology, Equity and K-12 Learning

Roy D. Pea

Center for Technology in Learning, SRI International

My plan in this paper is to provide a brief background on current research and policy issues in equitable access to information technology and the Internet for K-12 learning. I direct a center, funded by the National Science Foundation, called the Center for Innovative Learning Technologies, or CILT (http://www.cilt.org). Each year we bring together a community of top researchers, educators, developers, and policy makers to design informed responses to pressing challenges in learning technology innovation and research.

This year at CILT 2000 in Washington DC, we asked about what the key policy issues are that face learning technology innovators concerned with technology and equity. While these concerns are not always central to the research work conducted by this interdisciplinary field, as empowering and fundamental roles for technology use throughout society become more evident, issues of equitable access to technologies that make a difference to learning and teaching become more central to address.

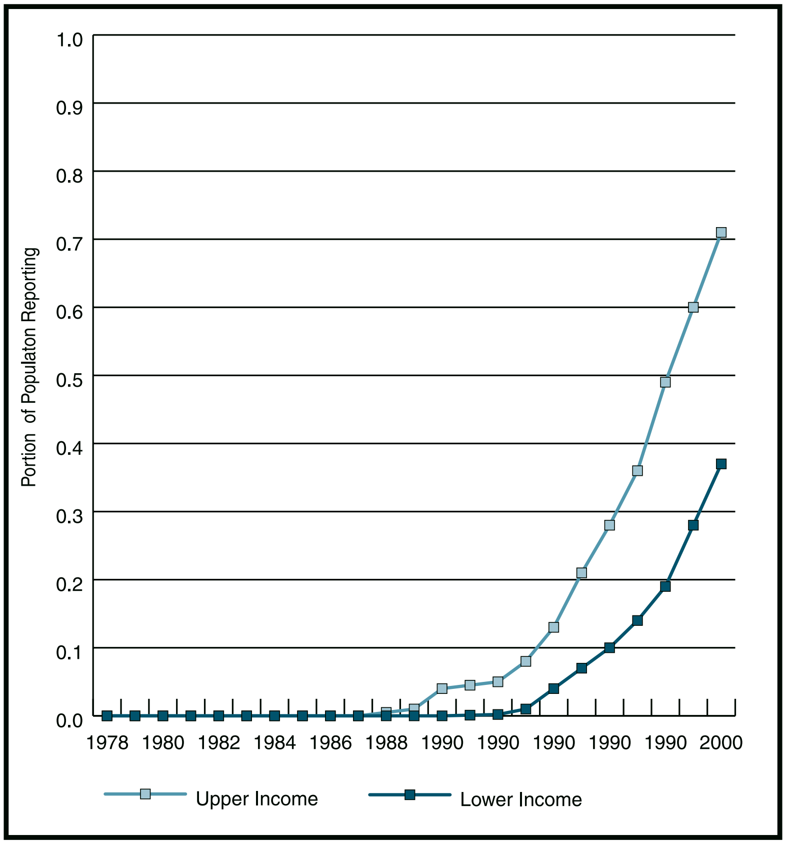
We have been very influenced in our thinking about these matters by the rationale and the data provided by the U.S. Department of Commerce reports on Falling Through the Net:

"The Internet is becoming an increasingly vital tool in our information society. More Americans are going online to conduct such day-to-day activities as business transactions, personal correspondence, research and information-gathering, and shopping. Each year, being digitally connected becomes ever more critical to economic, educational, and social advancement. Now that a large number of Americans regularly use the Internet to conduct daily activities, people who lack access to those tools are at a growing disadvantage. Therefore, raising the level of digital inclusion - by increasing the number of Americans using the technology tools of the digital age - is a vitally important national goal." (Falling Through the Net: Executive Summary, U.S. Department of Commerce, October 2000.)

In the Executive summary, the increasingly fundamental role of the Internet in American society and its basic activities is used to argue for the crucial policy goal of digital inclusion. Similarly, there has been throughout 2000 a profusion of policy reports in which the digital divide and digital inclusion issues are raised, analyzed and discussed in ways relevant for K-12 Education. These include:

1. "Resolving the Digital Divide" (The President's Information Technology Advisory Committee, also known as PITAC)
2. "Who's not on-line" Internet and American Life Project (Pew Foundation)
3. "On-line content for low-income and under-served Americans" (Children's Partnership)
4. "Disconnected, Disadvantaged, and Disenfranchised" (Consumers Union; Consumer Federation of America)
5. "Internet access in public schools and classrooms: 1994-1999;" and "Teacher use of computers and the Internet in public schools: 1999" (U.S. Department of Education, National Center for Educational Statistics, or NCES)

Figure 1
Diffusion of Internet Use
Households Above/Below Median Income,
(Year of First Use of Current, Home Users)



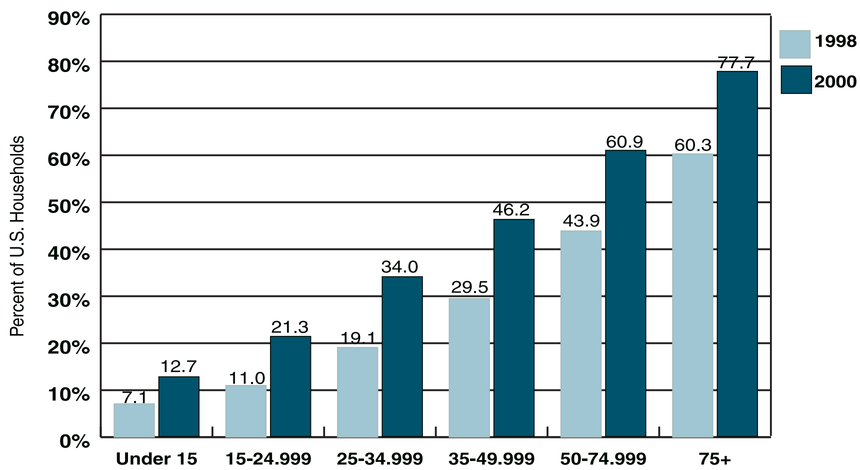
The terms of analysis for digital divide are worth reviewing for our consideration. The United States Commerce Department defines digital divide as "differences in the shares of each group that is digitally connected." The groups and data that are analyzed in the Commerce Department reports include income level, educational level, race and ethnic origins, location, disabilities (for example, visual, manual dexterity, hearing, and mobility), age level, household type (single or two-parent), and gender.

One of the most striking statistics is presented in the key policy report called Disconnected, Disadvantaged, and Disenfranchised. In this figure, the authors depict the proportion of the population above and below the median income and the diffusion of Internet use.

As you can see (figure 1), the year of first use of current home-based Internet users is dramatically different in this high-low demographic split, which represents a rate of roughly double the proportion of above-median income households using the Internet in 2000 over below-median income households (about 71% vs. 37%).

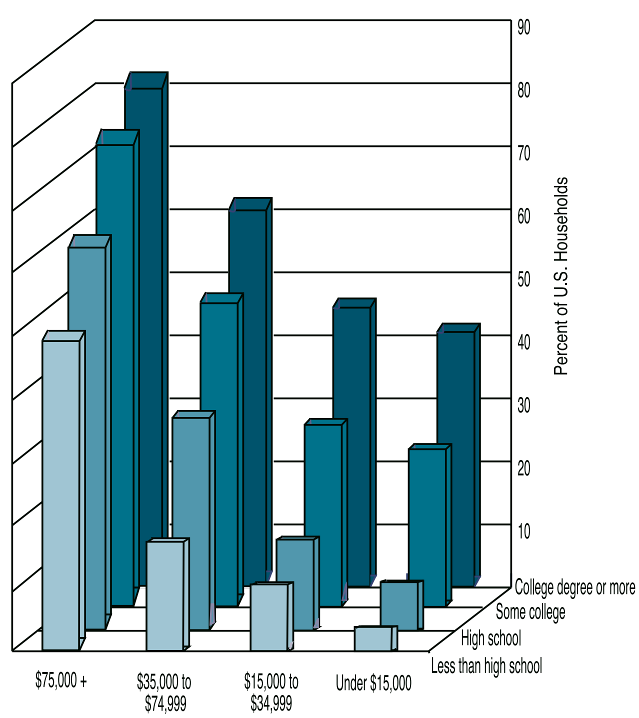
In a histogram representation from the U.S. Department of Commerce's Falling through the Net report last year (figure 2), this simple above-below median income split is examined in more detail. Results are differentiated to indicate how, at six different levels of household income, from under $15K at the low end to over $75K at the high end, the percentage of U.S. households with Internet access ramps up. There is a vast six-times spread over this range,

Figure 2
Percent of U.S. Households with Internet Access
By Income ($000s), 1998 and 2000



Source: NTIA and ESA, U.S. Department of Commerce, using U.S. Bureau of the Census Current Populations Survey supplements.

Figure 3
Percent of U.S. Households with Home Internet Access
By Income and Education, 2000



Source: NTIA and ESA, U.S. Department of Commerce, using U.S. Bureau of Census Current Population Survey supplements.

with the under-$15K household income percentage of internet-enabled households at 12.7% compared to 77.7% for the $75K-plus households.

This graphic also dramatically illustrates the pace of this appropriation of Internet access by U.S. households, with a sizeable spike of 30% or more from 1998 to 2000 at most of these household income levels, with the most sizeable base percentage increases at the lower income levels, nearly doubling.

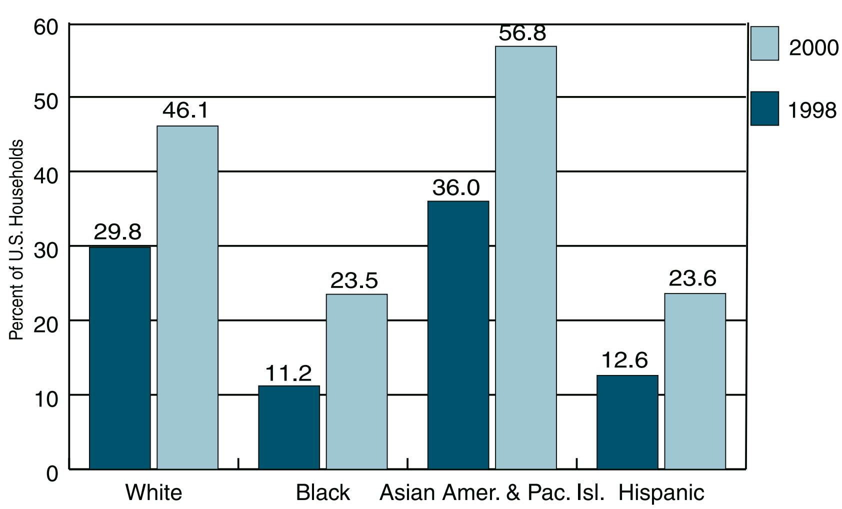
Income level is one key predictor and digital divide for Internet access, but education is also very significant. This two factor effect is illustrated in the preceding graphic (figure 3), that provides a steep slide down from a peak of about 80% for households with a college degree education or more and $75K-plus annual income level, down to a nadir of about 5% for those with less than high school education and annual income under $15K. At this lowest corner of the graphic, there is very little use of the Internet at home.

It should not come as a surprise that such data affect the K-12 students in those households. 70% of parents with incomes of $75K or more report that one or more of their children use the Internet, compared to 35% of parents with incomes under $40K (Source: "Safe and smart: Research and guidelines for children's use of the Internet," 2000).

Now let's consider the differential access for U.S. households by race and ethnic origin from 2000 data (figure 4): Asian-American and Pacific Islanders lead (56.8%), with Whites close behind (46.1%), and Hispanic (23.6%) and Black (23.5%) households much less connected to the Internet. It is critical to note the astounding pace of connection to the Internet from 1998 to 2000, with a near-doubling of connectivity rate for the Black and Hispanic households and a roughly 50% increase over that two-year period for the White and Asian American/Pacific Island demographic groups.

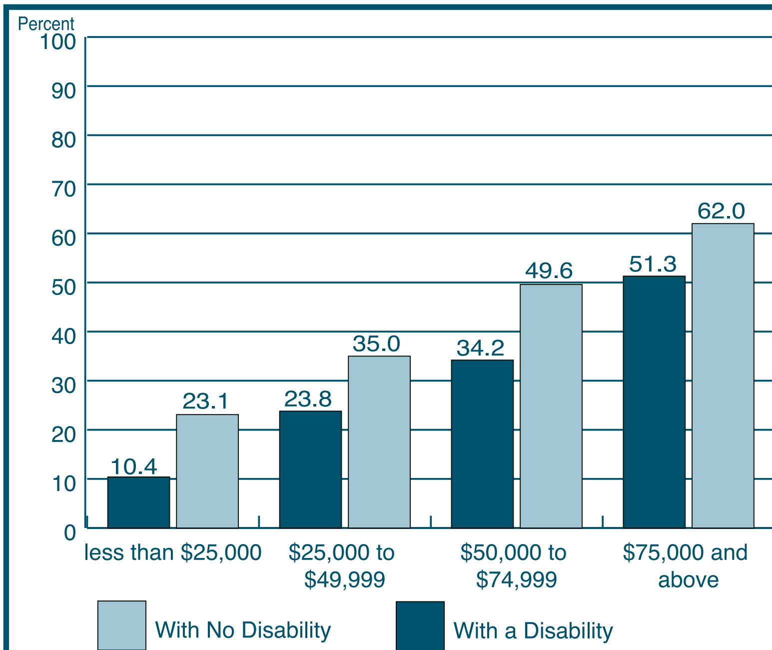
When we turn to age as a demographic consideration, there are profound differences that appear in Internet use as well, with December 1998 and August 2000 as data points. In the

Figure 4
Percent of U.S. Households with Internet Access
By Race/Hispanic Origin, 1998 and 2000



Source: NTIA and ESA, U.S. Department of Commerce, using U.S. Bureau of the Census Current Populations Survey supplements.

Figure 5
Internet Access at Home by Income and Disability Status, 1999



Source: Survey on Income and Program Participation, research data file (Aug-Nov 1999; Wave 11), U.S. Bureau of the Census, U.S. Department of Commerce

2000 data, the percent of Internet users is at its peak at 14 years of age with 65% of respondents, with a usage plateau of 50-60% of users from 18 to 52 years of age, and then we see a precipitous slide down to under 10% by age 80. Over the 1998-2000 period, there is increasing adoption at all age levels, with greater percentage gains among the more senior age cohorts.

Disabilities (figure 5) provide yet another major demographic area for a look at digital divide issues in Internet access (Source: Table III-1, Survey on Income and Program Participation, Research data file (August -November 1999, Wave 11), U.S. Census Bureau, U.S. Department of Commerce). With a total population over 16 years of age in late 1999 of 208.8 Million, 21.8%, or 45.4 Million, has some form of disability. These disabilities include: Difficulty Walking (9.2 million, or 4.4%), Vision Problems (7.3 million, or 3.5%), Hearing Problems (7.0 million, or 3.3%), Difficulty using Hands (6.3 million, or 3.0%), and Learning Disability (2.9 million, or 1.4%). Even considering income-level equivalence, there are profound negative consequences of disability access for Internet access at home, with the greatest relative percentage digital divides at the lower income levels.

In summary, the U.S. Department of Commerce has highlighted "progress but concerns" in its most recent reports summarizing changes over the past few years across the different categories for its empirical analyses of the digital divide: income level, educational level, race and ethnic origins, location, disabilities, age level, household type (single or two-parent), and gender. The Falling through the Net report emphasizes that:

"If current trends continue, we expect more than half of all U.S. households will be connected to the Internet by the end of 2000, and more than half of all individuals will be using the Internet by the middle of 2001. We are approaching the point where not having access to these tools is likely to put an individual at a competitive disadvantage and in a position of being a less-than-full participant in the digital economy. Most groups, regardless of income, education, race or ethnicity, location, age, or gender are making dramatic gains. Nevertheless, some large divides still exist and groups are going online at different rates."

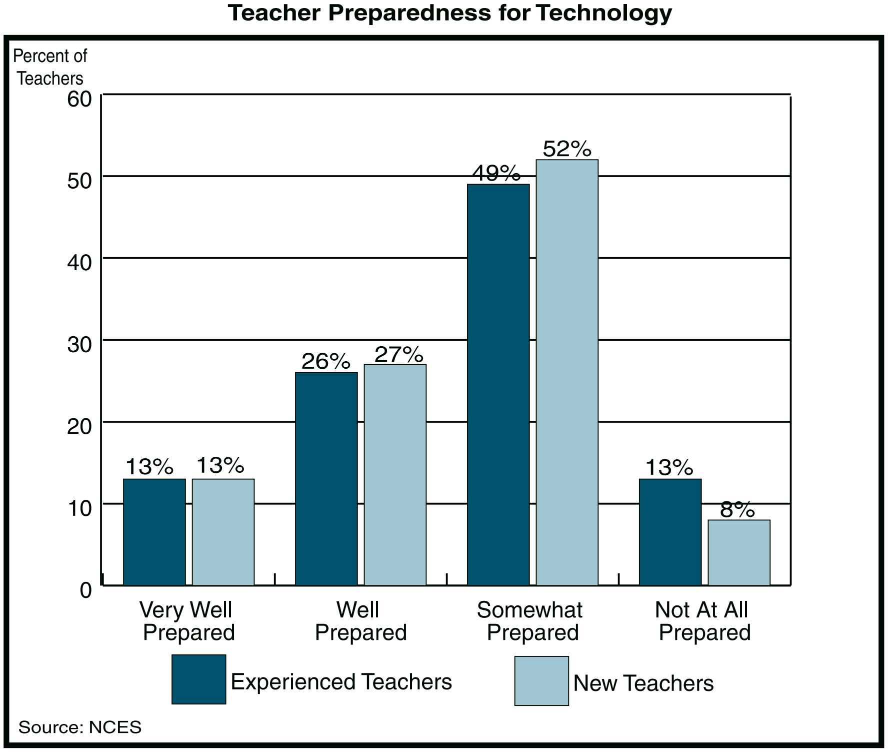
IN EDUCATION, SCHOOL INTERNET ACCESS IS GROWING RAPIDLY

After many years of a slowly shrinking ratio of students per computer in American schools, there has been exceptionally rapid adoption of Internet access in K-12 schools. Data from the U.S. National Center for Educational Statistics (NCES) reveals that from 1994 to 1999, the percent of schools with Internet access in public schools has grown from 35% to 95%; the percent of Instructional Rooms that are connected to the Net has increased from 3% to 63%. Furthermore, in 1999, Internet connectivity methods have developed considerably beyond the assumption of slow dial-up modem connections-fully 64% of schools in 1999 had dedicated WAN lines, with only 14% using dial-up. And the classroom computers are not isolated from one another within these schools, as 84% of public schools reported use of LANs in 1999 (unfortunately not reporting what proportion of their classroom computers are connected to their LANs).

NONETHELESS, THERE ARE SCHOOL-TYPE EFFECTS IN INTERNET ACCESS

NCES data released in its February 2000 report demonstrated a significant digital divide in schools serving lower-income communities. Schools with the highest concentration of poverty had 16 students per instructional computer with Internet access, compared to 7 among schools with the lowest concentration of poverty. And beyond such SES effects, there were important results for geographical region and for school size. Rural schools and

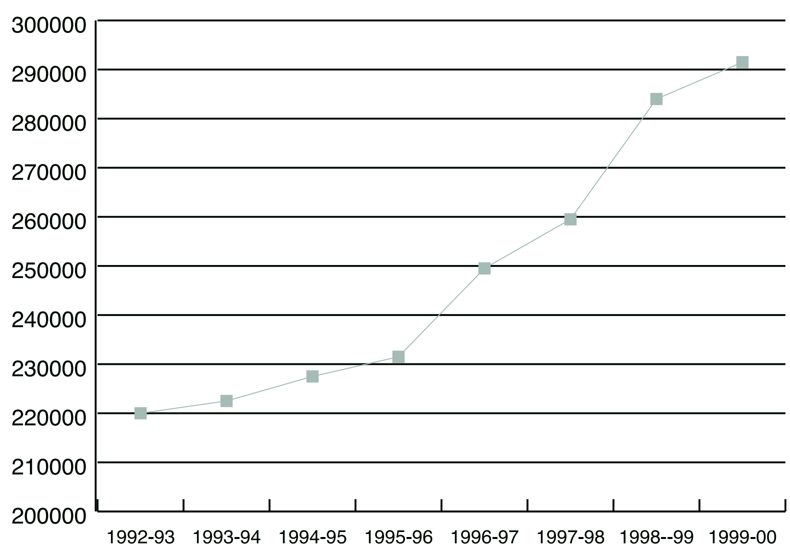
Figure 6
Teacher Preparedness for Technology



smaller schools are ahead of city school and larger schools in their provision of instructional computers with Internet access. In rural schools, there are 7 students per computer but in city schools, 11 students per computer. In smaller schools, there are 6 students per computer, but 10 students per computer in large schools.

The assumption in these benchmark comparisons are that more meaningful interactions with technology-enhanced learning environments are more likely with more computer access in the classroom. We need to know far more about which specific applications and digital content are being used in these classrooms, by which range and groups of students, and with what learning outcomes under different conditions of implementation, such as

Figure 7
Historical Demand for Teachers in California, 1992-93 to 1999-2000



Sources: CDE (1998, 1999, 2000)

level of teacher preparation, indexing to academic standards of the learning applications, home access to technology, and other such systemic concerns with learning environments (Roschelle et al., 2001).

TEACHER PROFESSIONAL DEVELOPMENT PROVIDES CRITICAL CHALLENGES

After years of focus on students and computer learning, teachers' preparation for integrating computers into their instruction has become a key topic for research. The most recent work in this vein from NCES is telling: fully 2/3rds of K-12 teachers use computers or the Internet for some classroom purposes, but most do not feel well prepared (figure 6). And this preponderance of ill-preparedness fits with data from self-reports on training: 81% had under 10 hrs of training with technology in the previous year (Source: Market Data Retrieval).

A related challenge to teacher preparedness to help students utilize the tools on the access side of the digital divide is that of recruiting and supporting professional development for a

Figure 8
Average Percent Underqualified Teachers by School-Level API Score, 1999-2000

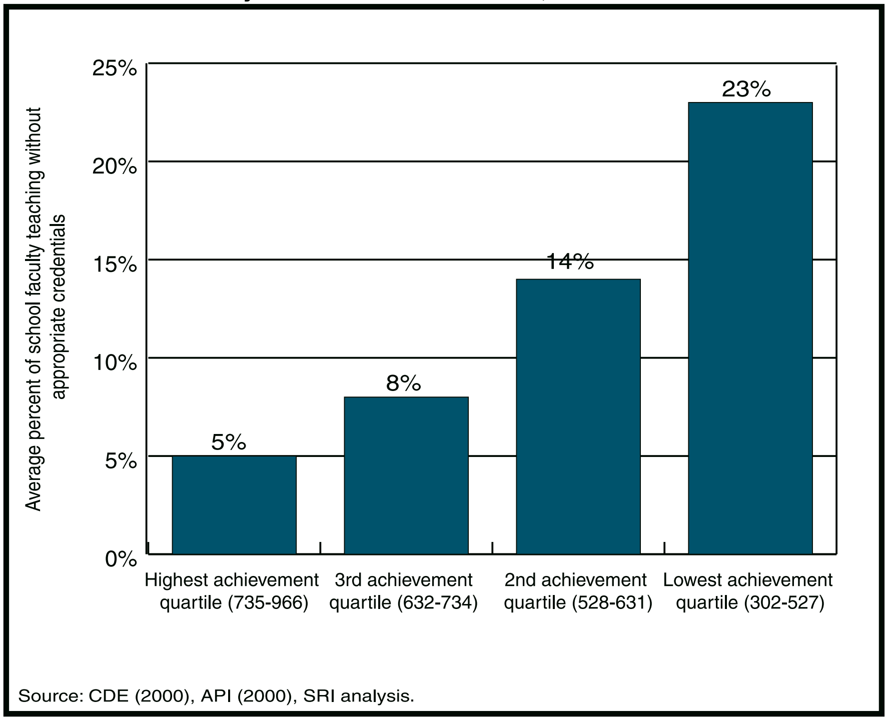
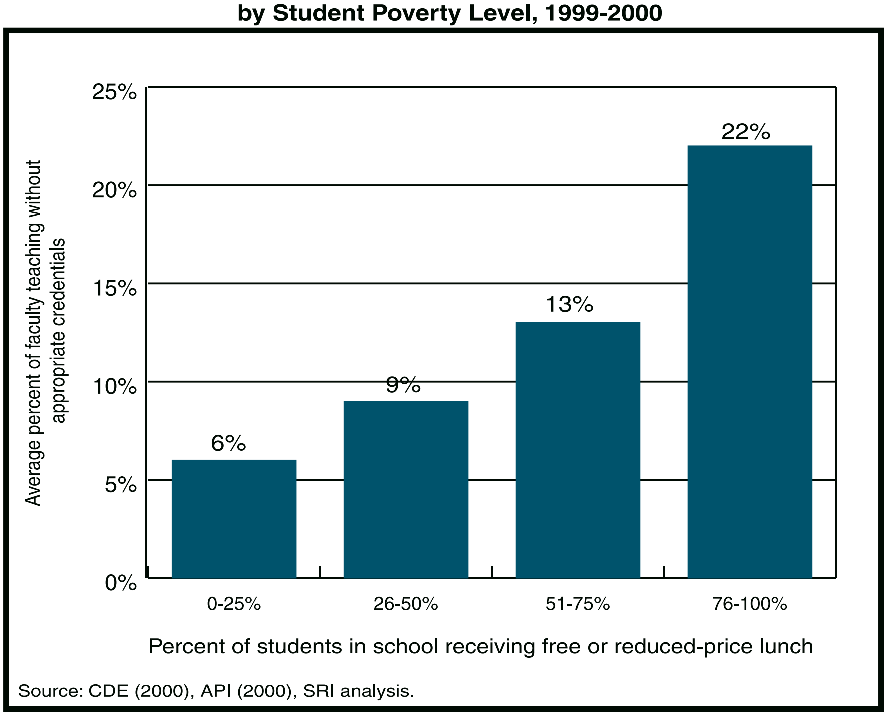


Figure 9
Distribution of Underqualified Teachers by Student Poverty Level, 1999-2000



generation of new teachers. Due to retirements and increasing student enrollments, the projection for the number of newly hired public school teachers needed by 2008-09 ranges from 1.7 million to 2.7 million. (Source: U.S. Department of Education, Hussar, 1999).

A study conducted by SRI International, supported by Center for the Future of Teaching and Learning, and released in late 2000, identified the scope of the challenge for the State of California: with the demand for teachers at 291,000 and growing rapidly (figure 7).

And this report has sadly documented the present state of under-qualification among California's teachers. 14% of all California's teachers are under-qualified (over 40,000), with emergency permits or waivers, and 24% of schools have 20% or more under-qualified teachers (figure 8). And this study answers the question, with unfortunate results: Who are children most likely to be taught by an under-qualified teacher?

Quite simply, the average percent of under-qualified teachers goes up considerably as a function of the poverty level of the school (figure 9). And we can see the additional correlate of teacher under-qualification with student under-performances. When considering achievement data for students in their school-level API scores by quartile, we can see that for the four achievement levels that in the lowest achievement quartile, fully 23% of teachers are under-qualified and yet, in the highest achievement quartile, only 5% of teachers are under-qualified.

DIGITAL DIVIDE AND CALIFORNIA'S UNDER-QUALIFIED TEACHERS

Although the SRI report documents the scope and seriousness of California's problems with under-qualified teachers, we do not yet know about the relationships of high-poverty level schools, under-qualified teachers, and digital inclusion. Given the trends in high-poverty and digital access for home Internet use and school Internet use, we may conjecture that high-poverty level schools will not only have more under-qualified teachers, but less digital inclusion.

EXTENSIVE FEDERAL, STATE AND PRIVATE EFFORTS

In considering this California policy question, it is worth highlighting the extensive federal, state and corporate efforts that have contributed to addressing the digital inclusion issue for K-12 education. Most significant, by all accounts, is what is commonly called the E-Rate program. The E-Rate program was developed following the Congressional authorization of the 1996 Telecommunications Act (as the bipartisan Snowe-Rockefeller-Exon-Kerrey amendment), and has been able to provide since January 1998 over $5.7 Billion as a universal service program for public K-12 schools and libraries by discounting Internet and telecommunications technologies and services. With discounts from 20-90%, depending on level of poverty, the poorest schools and libraries have been benefiting most, from every state in the union. There have been three years of funding, beginning in January 1998, with 83,188 applications funded as of December 1st, 2000 (http://www.sl.universalservice.org/). Carvin (2000), in a report funded by the Benton Foundation, provides a compelling case study series for four Midwestern cities and what the E-Rate program has been able to achieve for them.

Other federally-motivated efforts have included the U.S. Department of Education's funded partnerships among communities, industry, governments and education known as the Technology Literacy Challenge Fund; an ambitious program in its second year from the

U.S. Department of Education called the PT3 program that is seeking to transform processes of teacher preparation in the U.S. to integrate effective uses of technology in instruction, and Community Technology Center programs for low-income areas.

Companies that have contributed substantially in addressing K-12 digital divide issues include, in alphabetical order: AOL, AT&T's Learning Network, Cisco Academies, Ford, Intel's Teach to the Future Program, and Microsoft.

GOING BEYOND THE ACCESS QUESTION: "ACCESS TO WHAT? AND FOR WHAT PURPOSE?"

While the statistics on computer and Internet access in schools illustrate remarkable and measurable progress toward the access goal in the 1996 National Educational Technology Plan developed by the U.S. Department of Education, educators, researchers, parents, and policymakers alike have been digging deeper. Once the NetDays are complete, and your school is wired, and there are enough computers in your K-12 classroom to enable students to work productively in small groups for some part of the school day, the critical question is what have I now gained access to as an educator or student, and for what purposes will such access be useful?

As policy studies and reports have begun to tackle these questions, they have begun to document new and emerging divides that have significant "digital" aspects. These new divides include "Content Divides" and "Quality of Service Divides."

A chilling report from the Children's Partnership (March 2000) highlights how "50 million Americans face one or more content-related barriers that stand between them and the benefits offered by the Internet." The barriers they document and analyze include: (1) high literacy levels (i.e., the level of reading skill required by most web sites is beyond meaningful access for prospective Internet users with low literacy levels); (2) English-only websites (as the language used on websites is predominantly English); (3) Lack of cultural relevance (for many ethnic and cultural groups); and (4) Lack of local information (for community, healthcare, education, environmental, employment, and other vital purposes). They propose a variety of actions that could help ameliorate these content divides for the Internet and its users.

New "Quality of Service Divides " are emerging in studies that recognize that Internet access alone is not the appropriate metric, as there are many differentiating qualities of that access that influence the purposes to which the access may be put. The most evident of these QOS divides is perhaps speed of connectivity, with time requirements for rich media (audio, video) and software downloads prohibitive for modem-only Internet access. And it is highlighted in the new e-learning national plan (see below): "The quality of Internet access is critical. Broadband access will be the new standard. Slow, unreliable connections that cannot support interactivity or multi-media content will no longer be sufficient. To take advantage of access to technology for improved teaching and learning, it will become increasingly important to build and support network infrastructures-wireless, desktop or handheld-that allow multiple devices to connect simultaneously to the Internet throughout every school building and community in the nation."

But the broadband QOS divide is simply the beginning. The telecommunications industry and various dot.coms are diligently advancing the state of the art of QOS differentiation so that packets of information can be streamed with different levels of priority, as a function of costs or other metrics. So even as the pipelines for telecommunications widen, and the connectivity to schools and homes increases in its breadth and speed, the K-12 educational sector is unlikely to be anywhere near the head of the queue for information packet transmissions. Whether these new developments will create new and significant QOS divides that negatively impact learning and teaching processes and outcomes remains to be seen. But it is a topic on which we should remain vigilant.

A NEW E-LEARNING NATIONAL PLAN

In December 2000, the U.S. Department of Education released a very significant update to the 1996 National Educational Technology Plan that had defined four educational technology goals: a computer in every classroom and every classroom wired to the Internet, computer training for all teachers and instructional software available to all students (http://www.ed.gov/Technology/Plan/). After $8 billion of investment toward these goals during the Clinton administration, according to this document, the time has come to move beyond access to focus on patterns of use. The new five goals highlight the importance of going beyond counting computers and connections to now identifying effective digital content and technology applications and their conditions of implementation, and focusing, with the third goal below, on the new literacies that are emerging in an information society. The teacher focus is also distinctive: from an earlier concern with "training" in technology use to a new focus on effective use and integration of technology tools in support of students' achievement of higher learning standards.

2000 NATIONAL EDUCATIONAL TECHNOLOGY GOALS

Goal 1: All students and teachers will have access to information technology in their classrooms, schools, communities and homes.

Goal 2: All teachers will use technology effectively to help students achieve high academic standards.

Goal 3: All students will have technology and information literacy skills.

Goal 4: Research and evaluation will improve the next generation of technology applications for teaching and learning.

Goal 5: Digital content and networked applications will transform teaching and learning.

The e-learning report highlights illustrative case studies that show exemplary developments toward these objectives, while also highlighting specific national, state, local and private sector actions that will be necessary for all student and teachers to take full advantage of the new opportunities from emerging technologies for improving learning and teaching for all.

PROVIDING INTERNET ACCESS ALONE IS AN OVER-SIMPLISTIC RESPONSE

As we reflect on the extraordinary attention that has been devoted to issues of the digital divide and digital inclusion over the past several years, it is worth emphasizing how limiting such considerations are if taken too much in isolation.

"Digital inclusion" for social mobility requires skills and knowledge ranging from basic literacy to new technical fluencies for participation—with different strategies for home, school, community, and work. There are skills and fluencies that Internet users will need to have available or to achieve in order to take real advantage of the Internet's resources for the diverse purposes of lifelong learning and living, as addressed in the National Research Council report (1999) on Being Fluent with Information Technologies.

And there are multiply-determined pathways—social, economic, political—to the creation of groups found to define the "digital divides" in the studies by the U.S. Department of Commerce and others. To work on universalizing access alone, and expect that social policy in this realm can eradicate deeper economic or educational differences is to minimize how those differences are constructed.

Finally, we cannot ever forget that there are other fundamental divides to tend to than digital divides. Differences in access to parent care, nutrition, shelter, safety, healthcare, and opportunities to learn and work remain obstacles to fulfillment of the promise of the human condition and everyone's ability to live a quality life and contribute to the greater good of society.

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THE DIGITAL DIVIDE: DIAGNOSIS AND POLICY OPTIONS

Roger G. Noll and Dina Older-Aguilar

The digital divide refers to differences in the use of advanced information technology (computers and the Internet) among various socioeconomic and demographic groups. The most important facts about the use of information technology are as follows.

- **Computer ownership and usage is growing very rapidly**. More than half of American households own a computer, and more than two-thirds of these households use the Internet. About a fifth of Americans access the Internet only outside the home, either in school, on the job, at the library, or in the home of a friend or relative.
- **Computer use and Internet access vary enormously by income, educational attainment, age, and ethnicity.** For example, over 85 percent of households with more than $75,000 annual income own a computer compared to 22 percent for households with incomes under $5,000. Holding income constant, Asian-American households are nearly twice as likely to own a computer as Black and Hispanic households, with White households in between. However, among all groups Internet usage among those who own a computer is quite similar, ranging between two-thirds and three-quarters of computer owners among all groups. The most plausible explanation is that Internet access is a primary motivation for acquiring a home computer.
- **Both computer ownership and Internet use are growing more rapidly among groups with historically low utilization of these technologies, so that in this sense the digital divide is closing.** The absolute gap - the difference in the number of households with a home computer and Internet access - is still growing; however, the growth in the absolute gap cannot persist because among households with the highest incomes and educational attainment, penetration is nearing saturation. Thus, an important and as yet unanswered question is how fast and by how much the digital divide will narrow due to continuing rapid growth among groups with historically low usage.

POLICY ISSUES

The digital divide has given rise to four general policy concerns:

- **universal service**
- **equal access**
- **content diversity**
- **educational uses of information technology**

The first two represent policies about providing access to a larger proportion of the population, and the latter two refer primarily to the uses of the system by those who have access to it. Obviously, these issues are related by the "chicken-egg" problem that pervades all information technologies. On the one hand, the extent to which people want to have access depends on the information services that are available to them, but on the other hand organizations - even non-profit service organizations - are only interested in developing information services if a significant number of people will make use of them. **Thus, policy actions that increase access will tend to generate more services, and policies that increase services will tend to cause more people to become connected.**

This section summarizes the policy issues and alternatives in each of these four categories.

UNIVERSAL SERVICE

For several decades U.S. telecommunications policy has espoused the goal of connecting every household to the telephone network. This policy has had three main elements: rate-averaging, service cross-subsidization, and lifeline support.

Rate-averaging means that the prices of core telephone services - the installation fee, the basic monthly access charge, and long-distance tariffs - did not differ by as much as costs across different communities. As a result, prices in high-cost areas - usually rural communities with very low population density - are substantially below cost.

Service cross-subsidization refers to the practice of setting average price above average cost for some services in order to subsidize an average price that is below cost for some other service. For example, the cost of providing basic monthly access for businesses and residences is very similar, yet business prices are usually two or three times as high as residential prices. In addition, long-distance prices generally have exceeded costs, generating profits that are then used to keep basic monthly access charges below average cost.

Lifeline service refers to a direct subsidy to low-income households to cover part of their monthly phone bill (which itself is subsidized by the other two components of universal service). The revenues to pay for this subsidy are raised from a tax on other telephone services.

Research on universal service policies concludes that the program is very costly yet has very little effect on telephone penetration. Universal service policy has little effect for two reasons. First, nearly all consumers are not price-sensitive in acquiring telephone service, so subsidizing it induces few new customers. Second, the subsidies arising from rate-averaging and cross-subsidization are not related to ability and willingness to pay. Therefore, a great deal of the money is spent on relatively high-income households (sometimes for multiple access lines) who would choose to buy telephone access even if the price of access service were set equal to cost. Virtually all research concludes that only very low-income households are likely to respond to lower telephone access prices, and so that only lifeline service has a measurable effect on telephone penetration, yet lifeline subsidies account for a small proportion of the total cost of universal service policy. As a result, policy has generally tended to favor "rate re-balancing," or moving prices nearer to cost; however, a great deal of rate-averaging and cross subsidy remains.

Universal service policy is related to the digital divide in two ways.

1. **Ordinary telephone lines remain the principal means of computer access to the Internet**, so telephone access is a necessary component of a policy to increase computer and Internet use.
2. The Telecommunications Act of 1996 creates a new process for identifying technologies that are candidates for inclusion in the universal service policy regarding telephones. According to the new criteria for inclusion in universal service, **home computer access to the Internet could become part of the universal service program within a few years**. And, even if universal service in telephony does not incorporate advanced information technology, the same type of tax-subsidy methods could be used in computer usage as are used in telephony.

A key difference between computer services and telephone services is that the former does not have significant geographic variation in cost, so that rate averaging would have no role in a universal service policy for advanced services. **If California were to adopt a policy of subsidizing advanced information technology in the home, such a program would focus on hardware and software costs of a computer plus the costs of Internet access.** Over ordinary telephone lines, Internet access is obtained by having a computer modem that enables the computer to dial the telephone number of an Internet Service Provider (ISP). The ISP gives the customer access to many other websites that provide Internet services (e-commerce, e-news, e-education, etc.), and usually provides e-mail, search engines, and chat rooms as well.

The cost of Internet access is higher than the average cost of telephone service. In urban areas, the average cost of local service is in the range of $20-25 per month, while the price (including both state and federal monthly access charges) is around $15. This price structure implies that, on average, residential customers receive a subsidy for local telephone service that is about one-third of the cost. By comparison, a low-end computer plus software plus Internet access is more expensive, running about $35-40 per month. In some countries (including Mexico), companies offer the combination of computer hardware, software, and ISP service for roughly this price. Thus, **a policy to use subsidies to narrow the digital divide could be quite costly, especially if it mimicked universal telephone service policy by providing a subsidy to all residential households**, not just those who need a subsidy to be able to afford service. For example, a subsidy equal to one-third of the cost for all households would amount to at least $12 per month per household. If this subsidy (like the existing telephone universal service subsidy) were granted across the board to all households in the state, it would cost over $1 billion per year just for the California households that already have a computer and use the Internet.

An alternative strategy is a **lifeline-like targeted subsidy for low-income households**. Because computers and Internet service are more expensive than telephone service, this subsidy probably would have to be significantly larger than the subsidies for lifeline telephone service that are now available. Moreover, the income threshold for qualifying for a subsidy probably would have to be higher than for lifeline service because of the greater cost of computers and Internet access compared to ordinary telephone service. This policy would also require further decisions to define the technical characteristics of the combination of hardware, software and access services that would constitute the minimum service bundle. Another decision is whether to allow competition in providing this bundle (using something like a voucher system for paying for access), and whether the voucher could be used for any combination of computers and ISP, or just the minimum bundle.

In summary, a plan to subsidize access to advanced information technology requires finding answers to many ancillary questions.

A more modest universal service subsidy would be to offer free training on computer and Internet use to first-time computer purchasers. Research indicates the ignorance and fear of computers is an important cause of hesitance to use advanced information technology. Moreover, some private business have succeeded in offering a combination of training, low-cost, refurbished computers, and Internet access at a low price. **A potential policy initiative is to work with these companies to expand their reach by subsidizing consumers who acquire their packages.**

Regardless of how Internet access services are subsidized, the cost of taxing telephone usage to generate the subsidy is very high. For example, the E-rate program subsidizes access by schools, libraries and health care facilities through a tax on telephone services. This tax inefficiently discourages telephone usage by causing usage prices to exceed their cost. The welfare loss through discouraging usage is very high, estimated to be between $1 billion and $2.5 billion annually. In general, it is very costly to finance any policy on a narrowly based tax because of the distortions that these taxes create in the economy. Thus, the social cost of subsidies for Internet access will be substantially lower if they are financed by a broad-based tax.

EQUAL ACCESS

Equal access refers **to policies that enable consumers to have access to multiple ISPs and Internet services**, and likewise for entrants into Internet services to have the ability to market their services to all consumers. Presently telephone companies are required to provide equal access in the sense that they cannot block ISPs from offering service to their customers through dial-up modems. In the present environment consumers can use their ISP to use any of a large number of free search services to find just about all web sites. Likewise, telephone companies that offer high-speed Internet access connections, such as ISDN or DSL, also must allow ISPs to connect to their customers using these technologies.

The equal access issue has arisen with respect to high-speed access over cable television. Here policy is in chaos. The 9th Circuit Federal Court of Appeals has ruled that **state and local governments cannot regulate or otherwise control high-speed access over cable television**, finding that the FCC has exclusive jurisdiction in this area. In turn, when approving the merger of TCI and AT&T (the nation's largest cable TV and long distance companies), the FCC initially ruled that the merged entity was not required to provide equal access. These decisions led AT&T Broadband (the new merged entity) to offer high-speed access only to customers of its affiliated ISP, Excite@Home. But other federal courts have ruled differently. Some have given jurisdiction to the states, while others have asserted that neither the FCC nor the states can regulate high-speed cable access. Meanwhile, the Federal Trade Commission, in reviewing the merger between AOL (the largest ISP) and Time-Warner (another large cable TV company), imposed equal access as a condition for approval of the merger. Also, the FCC is reconsidering its earlier decision not to impose equal access rules on high-speed cable access as well as its decision to impose equal access on telephone companies.

Eventually these contradictory policies will be resolved. **One possible result is that either the courts or the FCC will decide that the states, including California, should develop their own access policy.**

Equal access is related to the digital divide in two ways.

1. **Access restrictions may enable the suppliers of hardware for access** (whether over telephone lines, cable systems, or wireless telephony) **to capture more of the market for themselves**. If the number of providers of the hardware for high-speed access connections is too small to support competition, the result will be higher prices for Internet services, and hence lower penetration of the Internet among low-income households. To overcome these higher prices would raise the cost to the state of a universal service policy for high-speed access.
2. **Access control enables the designated ISP to control access to other Internet sites.** One business model is for the ISP to supply most Internet services itself, while another business model is to charge Internet service providers for allowing the ISP's customers to access them. In either case, the effect is less diversity and higher prices for Internet services. As above, **the effect here is to reduce the affordability of the**

Internet and hence penetration, especially among low-income households. And, lower penetration among any demographic group implies that fewer businesses will be attracted to provide Internet services for that group.

If competition for Internet access service emerges, equal access requirements are not likely to have much of an effect. Competition will give consumers choice among ISPs, which in turn will compete for customers in part by offering them attractive options for accessing other web sites. Likewise, if high-speed Internet access proves not to be very important, equal access may also not matter very much because companies that offer Internet services will not have a financial incentive to orient their services to high-speed access, thereby cutting off customers with low-speed access (ordinary telephone lines). However, in this case, ordinary telephone lines are likely to be the primary source of access, and so a problem could arise if telephone companies no longer were required to provide equal access to ISPs. Another problem arises if high-speed access is important, and is only offered by one or two companies, for then lack of competition in basic access can spill over into lack of diversity in Internet services.

A 9th Circuit decision prevents California from developing its own access rules; however, this situation could change. **A plausible possibility is that the FCC will assert jurisdiction, but invite states to make access policy subject to FCC review, as the agency does with telephone pricing issues. But until this time arises, California has no direct role in equal access policy.**

CONTENT DIVERSITY

While Internet use is growing, some people have abandoned it after a trial period, citing that Internet services are not worth the cost. **One way to encourage more use of information technology is to assist in the creation of a greater array of information content that is available to consumers** - in essence, to solve the chicken-egg problem for under-served groups by encouraging content creation for them. Government already has done some of this by creating agency web sites that either allow citizens to deal with that agency on-line or provide useful information to citizens. But E-government initiatives are in their infancy, and assuredly have not been designed with the thought of inducing more people to learn to use the Internet.

Government also has a role in regulating certain aspects of content. Many citizens fear that the Internet will be used to harm them, such as by invading their privacy or stealing their identity. Among citizens who do not use computers and the Internet, these fears are especially common. **Thus, effective government policies to assuage these fears, either through protective regulations or greater publicity of existing protections, could help close the digital divide.**

Of course, the main source of Internet content is certain to be the private sector. Whereas one can imagine a grants program to initiate interesting web sites (indeed, some foundations are supporting such activities), the vast majority of Internet services are not likely to be the result of direct subsidies. **Here the main role is likely to be to avoid interfering with private initiative.** For example, implicit taxes on telephone services discourage entry by private Internet service providers, as would the failure to assure easy Internet access to all web sites (such as might occur without equal access requirements).

EDUCATIONAL USES OF INFORMATION TECHNOLOGY

For at least a decade the prospect of using information technology to improve educational performance has been high on the policy agenda. Unfortunately, the research on the effects of computers in education has produced mixed results. Some individual programs have had significant effects on performance, but broad-based statistical studies finds that the correlation between computers in the school and performance actually is slightly negative. The implication of these findings is that how computers are used is far more important than whether they are present, and to date too little effort has focused on usage as opposed to presence.

The twin policy recommendations that arise from this research are as follows.

1. **At least as much needs to be spent on software and teacher training as on hardware and Internet access for computers to have a positive effect on educational performance.**
2. **Far more attention needs to be given to experimenting with the use of information technology and carefully monitoring the results.** At this point, we do not know enough to make clear recommendations about how computers can best be used or how teachers ought to be trained to use them.

APPENDIX A

BIOGRAPHIES OF AUTHORS

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Robert W. Crandall is a Senior Fellow in the Economic Studies Program at the Brookings Institution. He holds an M.S. and a Ph.D. from Northwestern University. He has specialized in industrial organization, antitrust policy, and the economics of government regulation. His current research focuses on regulatory policy in the telecommunications sector, with particular emphasis on competition in voice, broadband, and wireless services.

He is author of Who Pays for Universal Service? When Telephone Subsidies Become Transparent. (with Leonard Waverman), 2000; Talk is Cheap: The Promise of Regulatory Reform in North American Telecommunications (with Leonard Waverman), 1996; Cable TV: Regulation or Competition? (with Harold Furchtgott-Roth), 1996; The Extra Mile: Rethinking Energy Policy For Automotive Transportation (with Pietro Nivola), 1995; Manufacturing on the Move, 1993; After the Breakup: The U.S. Telecommunications Sector in a More Competitive Era, 1991; Changing the Rules: Technological Change, International Competition, and Regulation in Communications (with Kenneth Flamm), 1989; Up from the Ashes: The Rise of the Steel Minimill in the United States (with Donald F. Barnett), 1985; Regulating the Automobile (with H. Gruenspecht, T. Keeler, and L. Lave), 1986; The Scientific Basis of Health and Safety Regulation (with Lester B. Lave), 1981; Controlling Industrial Pollution, 1983; The U.S. Steel Industry in Recurrent Crisis, 1981; and numerous articles in economics journals, edited volumes, and popular publications.

Mr. Crandall has taught economics at Northwestern University, MIT, The University of Maryland, George Washington University, and the Stanford in Washington program. Prior to assuming his current position at Brookings, he was Acting Director, Deputy Director and Assistant Director of the Council on Wage and Price Stability.

ROGER G. NOLL

Morris M. Doyle Professor of Public Policy, Department of Economics

Stanford University

Roger G. Noll is the Morris M. Doyle Professor of Public Policy in the Department of Economics at Stanford University. Noll holds a Ph. D. in economics from Harvard University. He is the author or co-author of thirteen books and over 250 articles, including Sports, Jobs and Taxes (1997), Challenges to Research Universities (1998), A Communications Cornucopia (1998), and The Economics and Politics of the Slowdown in Regulatory Reform (1999).

DINA OLDER-AGUILAR

Ph.D. Candidate, Department of Economics

Stanford University

Dina Older-Aguilar is a doctoral student in economics at Stanford University. Her research focuses on education, private schooling and racial segregation. She is the co-author, with Patrick McEwan and Thomas Nechyba, of "The Effect of Family and Community Resources on Education Outcomes" a review and synthesis of current research on the role of neighborhoods and family settings in determining students' educational success. Prior to coming to Stanford, Ms. Aguilar completed her B.S. at the University of California at Berkeley and was an Analyst with the health care consulting firm, Lewin-VHI.

ROY D. PEA

Co-Director of the Center for Technology in Learning

SRI International

Roy Pea is Co-Director of the Center for Technology in Learning at SRI International (formerly Stanford Research Institute), in Menlo Park, California (http://www.sri.com/policy/ctl), and Consulting Professor in the School of Education at Stanford University. He also serves as Director for Teachscape, a company he co-founded that provides comprehensive K-12 teacher professional development services incorporating web-based video case studies of standards-based teaching and communities of learners.

Roy also directs the multi-institutional Center for Innovative Learning Technologies (http://cilt.org), funded by the National Science Foundation. One of its aims it to create a national knowledge network for catalyzing best practices and new designs for improving K-14 learning with technologies among researchers, schools, and industries.

Since 1981, Dr. Pea has been active in exploring, defining, and researching new issues in how information technologies can fundamentally support and advance learning and teaching, with particular focus on topics in science, mathematics, and technology education. Particular areas of interest are computer-supported collaborative and on-line community learning, scientific visualization, and hand-held computer learning. He has published over 100 chapters and articles on cognition, education, and learning technologies, and was co-author of the 1999 National Academy Press volume, How People Learn.

Dr. Pea was a John Evans Professor of Education and the Learning Sciences at Northwestern University (1991-1996), where he founded and chaired the Learning Sciences Ph.D. Program, and served as Dean of the School of Education and Social Policy. During 1995-96, he was a Fellow of the Center for Advanced Study in the Behavioral Sciences. Dr. Pea is a Fellow of the American Psychological Society. His consulting has included education program advisement for Ameritech, Apple Computer, ETS, George Lucas Foundation, MacArthur Foundation, Mellon Foundation, National Science Foundation, Russell Sage Foundation, Sloan Foundation, Spencer Foundation, the states of Illinois and California, and the White House Office of Science and Technology Policy. In 1978, he received his doctorate in developmental psychology from the University of Oxford, England, where he was a Rhodes Scholar.

RICHARD R. ROSS

Graduate Student, Department of Economics

Stanford University

Richard R. Ross is a graduate student in the Department of Economics at Stanford University specializing in industrial organization and econometrics. His current work investigates demand spillovers in industries with indirect network externalities. He has teaching experience in introductory economics and statistics. He holds a B.A. in economics from the University of California, San Diego.

GREGORY L. ROSSTON

Deputy Director

Stanford Institute for Economic Policy Research

Gregory L. Rosston is Deputy Director of the Stanford Institute for Economic Policy Research at Stanford University. He is also a Lecturer in Economics at Stanford University. Dr. Rosston served as Deputy Chief Economist at the Federal Communications Commission working on the implementation of the Telecommunications Act of 1996 and he helped to design and implement the first ever spectrum auctions in the United States.

Dr. Rosston received his Ph.D. in Economics from Stanford University specializing in the fields of Industrial Organization and Public Finance and his A.B. with Honors in Economics from University of California at Berkeley. Dr. Rosston has written extensively on the application of economics to telecommunications issues and is the co-editor of two books relating to telecommunications.

APPENDIX B

Hitachi
California Public Affairs Forum
Bridging the Digital Divide
December 9, 2000
List of Speakers

Welcome

John Hennessy, President, Stanford University
Paul Jennings, Professor of Civil Engineering & Applied Mechanics, Caltech
Masahiro Maeda, Corporate Officer, Hitachi, Ltd.

Opening Address

Larry Irving, Former Assistant Secretary, U.S. Department of Commerce

Presentations - Universal Service, Equal Access and Education

Moderator: Margaret Jane Radin, Director, Stanford Program in Law, Science & Technology
Robert Crandall, Senior Economist, Brookings Institution
Lawrence Lessig, Professor of Law, Stanford Law School
Loretta Lynch, President, California Public Utilities Commission
Roy Pea, Director of the Center for Technology in Learning, SRI International

"Town Hall" Meeting

Moderator: Kathleen Sullivan, Dean, Stanford Law School
Andy Andreoli, Director of Indian Education, State Department of Education
Ruben Barrales, President and CEO, Joint Venture: Silicon Valley Network
Bart Decrem, Co-Founder, Eazel
Sandra R. Hernández, M.D., CEO, The San Francisco Foundation
Marcia Linn, Professor of Cognition and Development, UC Berkeley
Tom West, Director, CENIC

Universal Service/Equal Access Panel

Moderator: Roger Noll, Morris M. Doyle Centennial Professor of Public Policy, Stanford University and Director, Program on Regulatory Policy, SIEPR
Arun Baheti, Director of e-Government, Office of the Governor
Heather Barbour, Assistant Secretary, Division of Science, Technology and Innovation, California Trade and Commerce Agency
Mike Lorion, Vice President Education, Palm, Inc.

Education Panel

Moderator: Karl Pister, Former Vice President, Educational Outreach, UC
Michael Cole, Professor of Communications, UCSD
Shelley Goldman, Program Director, WestEd
Mark Harris, Undersecretary for Business, Business, Transportation & Housing Agency
Chris Shultz, Policy Analyst for Technology, Office of the Secretary for Education

APPENDIX C

CCST REVIEW PANEL

Warren Baker, President, Cal Poly San Luis Obispo

Charles Kennel, Director, Scripps Institution of Oceanography

C. Judson King, Provost and Senior VP, Academic Affairs, University of California

Victoria Morrow, Vice Chancellor, Educational Services & Economic Development, California Community Colleges

Lawrence Papay, Sr., Chair, Sector Vice President, SAIC

Roy Pea, Co-Director of the Center for Learning Technology, SRI International

Karl Pister, Former Vice President-Educational Outreach, University of California, Office of the President, Chancellor Emeritus, University of California, Santa Cruz

James Rosser, President, CSU, Los Angeles

AnnaLee Saxenian, Associate Professor in City and Regional Planning, UC Berkeley

George Scalise, President, Semiconductor Industry Association

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