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Chapter 6

New Technology and Digital Worlds: Analyzing Evidence of Equity in Access, Use, and Outcomes

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There is broad consensus among educators, communication scholars, sociologists, and economists that the development and diffusion of information and communication technologies (ICT) are having a profound effect on modern life. This is due to the affordances of new digital media, which bridge the interactive features of speech and the archival characteristics of writing; allow many-to-many communication among people without regard to time and space, including mass collaborative editing of texts; facilitate the creation of a global hyper-indexed multimodal information structure; and enable content production and distribution in both writing and multimedia on a scale previously unimaginable (Jewitt, 2008; Warschauer, 1999). For all these reasons, computer-mediated communication can be considered a new *mode of information* (Poster, 1990), or a "fourth revolution in the means of production of knowledge" (Harnad, 1991, p. 39), following the three prior revolutions of language, writing, and print.

The previous revolution, brought about through the development and diffusion of printing, took centuries to unfold, as its full impact depended on the industrial revolution that Gutenberg's printing press preceded by several centuries (Eisenstein, 1979). Today, though, the development and diffusion of computers and the Internet occur simultaneously with a new economic revolution, based on transition from an industrial to an informational economy (Castells, 1996). This helps explain both why new media have spread so fast and also why they are so crucial to enabling full social and economic participation. As Castells (1998) concludes, based on his exhaustive socioeconomic analysis of this postindustrial stage of capitalism, "information technology,

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and the ability to use it and adapt it, is the critical factor in generating and accessing wealth, power, and knowledge in our time" (p. 92).

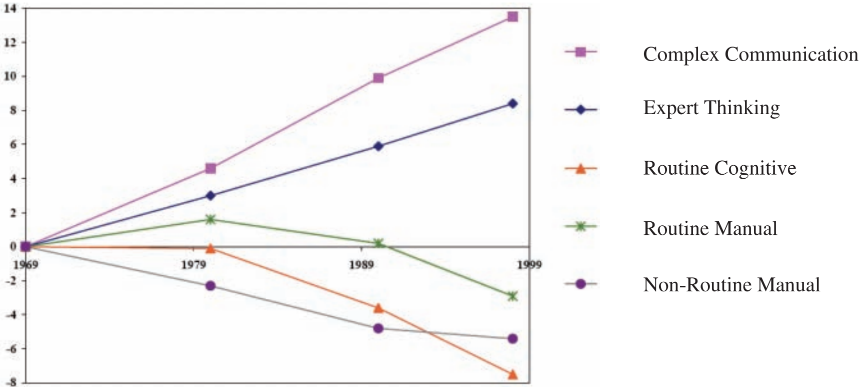
To emphasize this point, the U.S. Department of Labor's most recent *Occupational Outlook Handbook* lists "Network systems and data communication," "computer software engineers, applications," "computer systems analysts," "database administrators," and "computer software engineers, systems software" among the fastest growing occupations in the United States (U.S. Bureau of Labor Statistics, 2007). Looking more broadly, in the informationalist economy, high-paid blue-collar jobs based on manual labor are, for the most part, a thing of the past, with the previous split between blue- and white-collar workers now replaced by a three-way division among *routine-production workers* (e.g., data processors, payroll clerks, factory workers), *in-person service workers* (e.g., janitors, hospital attendants, taxi drivers), and *symbolic analysts* (e.g., scientists, engineers, executives, lawyers, management consultants, professors; Reich, 1991). The income, status, and opportunities for workers in the first two categories are continually diminishing, whereas symbolic analysts command a disproportionate and rising share of the wealth in the United States and other countries. And although some types of symbolic analysts might be considered as technology specialists, virtually all of them make extensive use of new digital media on a daily basis to identify, solve, and broker problems and to communicate complex concepts. Thus, access to new technologies, whether at home or at school, is critical to the development of symbolic analysts, but how such technologies are put to use is even more important, with a high premium placed on abstraction, system thinking, experimentation, and collaboration (Reich, 1991; Warschauer, 1999).

Levy and Murnane's (2004, 2005) detailed study of occupational patterns in the United States provides empirical support for the above analysis. Their examination of census data shows that from 1969 to 1999 the demand for jobs requiring complex communication rose nearly 14%, and the demand for jobs requiring expert thinking rose about 8%. In the same period, the demand for jobs requiring manual or routine cognitive tasks fell by 2% to 8% (see Figure 1). These numbers actually downplay the real changes, because they only reflect shifts *among* different occupations, not changes in skills required *within* the same occupation. Overall, the demand for jobs in which a computer can substitute for human thought has steadily declined, whereas the demand for jobs in which computers can complement and amplify the creativity and expert thinking of humans has steadily expanded.

The large and growing role of new media in the economy and society serves to highlight their important role in education, and especially in promoting educational equity. On the one hand, differential access to new media, broadly defined, can help further amplify the already too-large educational inequities in American society. On the other hand, it is widely believed that effective deployment and use of technology in schools can help compensate for unequal access to technologies in the home environment and thus help bridge educational and social gaps.

For these reasons, accurately assessing diverse demographic groups' experiences with technology, both in and out of school, has been an important priority for

FIGURE 1
U.S. Job Skill Demand, 1969–1999 (1969 = 0)



Source. Levy and Murnane (2005; based on data from Autor, Levy, & Murnane, 2003).

advocates of social and economic equality in the United States and elsewhere. Early efforts to do so focused on a narrowly defined *digital divide* of differential access to computers (see, e.g., National Telecommunications and Information Administration [NTIA], 1998). However, a danger to this approach is that it overly fetishizes technical matters. As Kling explains,

> [The] big problem with "the digital divide" framing is that it tends to connote "digital solutions," i.e., computers and telecommunications, without engaging the important set of complementary resources and complex interventions to support social inclusion, of which informational technology applications may be enabling elements, but are certainly insufficient when simply added to the status quo mix of resources and relationships. (Warschauer, 2003, pp. 7–8)

In this review, we take a much broader perspective on how to analyze issues of technology and equity for youth in the United States.[1] We begin with *access* as a starting point, but consider not only whether diverse groups of youth have digital media available to them but also how that access is supported or constrained by technological and social factors. From there we go on to the question of *use*, analyzing the ways in which diverse youth deploy new media for education, social interaction, and entertainment. We then move to the question of *outcomes*, considering the gains achieved by diverse groups through use of new media as measured by academic achievement, acquisition of 21st century learning skills, and participation in technology-related careers. Finally, we include one example—the disparities of involvement in computer science study—to illustrate how issues of access, use, and outcome are intertwined.

Conducting such a broad review is theoretically and methodologically challenging. The very concept of ICT or digital media is difficult to define, and could potentially include anything from a cell phone to a global positioning system. In this review, we not only focus on computers and the Internet but also consider other related media, such as video game consoles, if evidence suggests their use may be related to differential educational or social outcomes. In addition, the diverse ways that people use new media and the outcomes they might achieve are neither well understood nor easily gauged. For example, the value of *21st century learning skills* is broadly recognized (see, e.g., North Central Regional Educational Laboratory & the Metiri Group, 2003; Partnership for 21st Century Skills, 2009), but few studies have tried to operationalize those skills or measure their achievement. In spite of these limitations, we offer this review in the spirit of American statistician John Tukey (1962), who declared that "far better an approximate answer to the right question, which is often vague, than an exact answer to the wrong question, which can always be made more precise" (p. 62).

ACCESS

Notions of technology access have steadily shifted over the past 15 years from a narrow focus on the physical availability of digital media to a broader focus on the sociotechnical factors that influence whether and how people access technology (see, e.g., Warschauer, 2003). We adopt that broader perspective in this analysis, examining first the physical availability of Internet-connected computers and then the factors that support or constrain access, both in the home and school environments.

Home

Although people access the Internet from a variety of locations, home access allows a degree of flexibility and autonomy difficult to replicate elsewhere (see discussion in Dimaggio, Hargittai, Celeste, & Shafer, 2004; Fairlie & London, 2009). The degree of home access to computers by diverse demographic groups has been well documented in the United States through seven reports issued over the past 15 years by the NTIA (1995, 1998, 1999, 2000, 2002, 2004, 2008a). All seven NTIA reports were based on the Current Population Surveys (CPS) of about 50,000 U.S. households conducted by the U.S. Bureau of Labor Statistics and the U.S. Census Bureau. The CPS surveys collect general demographic data on a monthly basis and supplement those with specialized data at different times. Supplemental data on computer and Internet access were collected on seven occasions between 1994 and 2007 and formed the basis of the NTIA analyses.

The NTIA reports provide an excellent basis for evaluating the overall digital divide in the United States and how it has evolved over time. The CPS data they are based on are superior to other sources of data, such as those from the widely cited telephone surveys of the Pew Internet & American Life Project (see discussion below), because of the large CPS sample size; the methodological rigor in sampling; the in-person survey procedures by the U.S. Census Bureau, which achieves a response rate of more than 90%; and the consistency of questions asked over multiple years, thus allowing longitudinal analysis (U.S. Census Bureau, 2006). Taken as a whole, the reports suggest that steady progress has been made in extending home Internet access to low-income and minority households, but that gaps based on income and race still remain substantial and that there is a long way to go to achieve universal access.

The most recent NTIA study reports that a total of 61.7% of U.S. households have some type of Internet access at home. The largest gaps in home Internet access are observed between groups with differential income and educational attainment (see Table 1). Home Internet access by income varies from 95.5% for households earning more than $150,000 per year to 24.6% for households earning between $5,000 and $10,000 per year. (Households earning less than $5,000 per year have a slightly higher rate at 31.9%, perhaps because of the number of students at this income level.) Home Internet access by educational attainment of head of household varies from 18.5% for those with an elementary education to 84.1% for those with at least a bachelor's degree. These gaps by income and education are further exacerbated by the fact that it is precisely those households with little economic or human capital that are least able to provide other advantages for youth in the development of technological or academic skills.

Differences by race/ethnicity are not as large as by education or income but are still troubling. Rates of home Internet access by race vary from 75.5% for Asians to 41.5% for Native Americans. Figure 2, which shows home Internet access for Whites, African Americans, and Latinos over a 10-year period, indicates the persistence of a racial gap over time.

The low rate of Internet access by Latinos is caused to a large extent by a language divide. Based on his analysis of the CPS 2003 data, which included language as a variable, Fairlie (2007) reports that at that time only 13.1% of "Spanish only" Mexican or Mexican American families in the United States (i.e., those families in which all adults spoke only Spanish) had home Internet access, as compared with a home Internet access rate of 40.1% among English-speaking Mexican or Mexican American families in the United States, and that much of this gap held true even when controlling for education, family income, immigrant status, and other factors. Fairlie concluded that the digital divide between White, English-speaking non-Hispanics, and Spanish-speaking Hispanics in the United States was "on par with the Digital Divide between the United States and many developing countries" (p. 287). More recent data suggest that non-English-speaking Latinos remain a group with alarmingly low rates of Internet access and use (Fox & Livingston, 2007).

In considering all of the above, it is important to keep in mind that households with children tend to have greater access to computers and the Internet than the general population. According to the CPS data, 70.3% of family households with children younger than 18 years have Internet access at home, as compared with 57.4% of households without children. A study with children rather than households as the unit of analysis, conducted by the Kaiser Family Foundation, interviewed a nationally representative sample of 2,032 8- to 18-year-old children at school and found

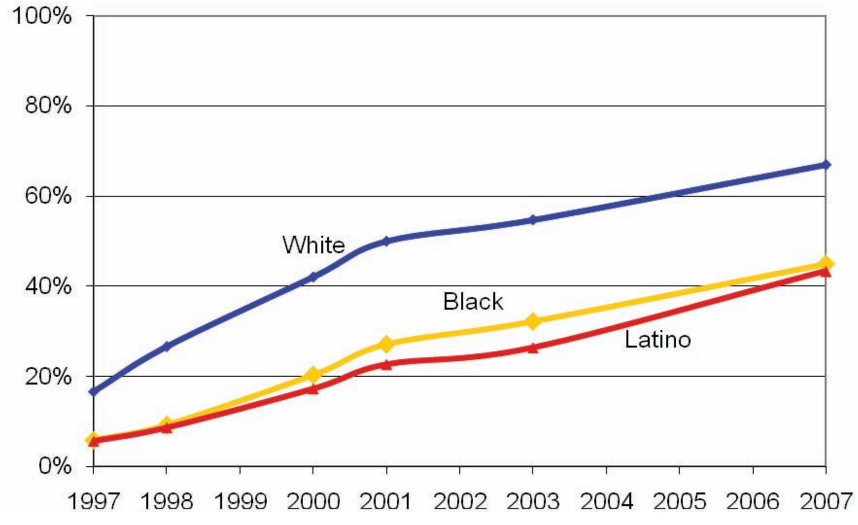
TABLE 1
Percentage of U.S. Households With Internet Access

	Percentage of Households With Internet Access			Broadband as Percentage of Those With Access
	Total With Access	Broadband	Dial-up	
Total households	61.7	50.8	10.7	82.3
Family income ($)				
<5,000	31.9	26.7	5.3	83.6
5,000-9,999	24.6	18.4	6.1	74.5
10,000-14,999	26.1	18.9	7.1	72.2
15,000-19,999	35.5	26.9	8.5	75.9
20,000-24,999	40.7	28.8	11.8	70.9
25,000-34,999	50.9	39.7	11.2	77.9
35,000-49,999	65.7	51.0	14.4	77.7
50,000-74,999	80.1	66.0	13.8	82.3
75,000-99,999	88.6	76.8	11.3	86.8
100,000-149,999	92.1	83.7	8.0	90.9
≥$150,000	95.5	90.3	5.0	94.6
Educational attainment of head of household				
Elementary	18.5	13.1	5.4	70.8
Some secondary	28.2	20.5	7.4	72.7
High school graduate	49.1	36.8	12.1	74.9
Some college	68.9	56.5	12.1	82.0
BA+	84.1	74.2	9.7	88.2
Race of head of household				
White	67.0	54.9	11.8	82.0
Black	44.9	36.4	8.4	80.9
Native American	41.5	29.8	11.2	71.9
Asian	75.5	69.1	6.1	91.5
Hispanic	43.4	35.2	8.0	81.1
Household type				
With child <18 years	70.3	59.5	10.6	84.7
No children	57.4	46.4	10.7	80.9

Source. National Telecommunication and Information Administration (2008b).

that 74% of them reported living in houses with Internet access, with the number rising to 78% of 11- to 14-year-olds and 80% of 15- to 18-year-olds (Roberts, Foehr, & Rideout, 2005).

FIGURE 2
Home Internet Access by Race/Ethnicity, 1997–2007



Source. Fairlie (2008).

Conditions of Access

Access to technology is not a binary division between information haves and have-nots; rather, there are differing degrees and types of access (see discussion in Warschauer, 2003). People without access at home may use the Internet at libraries, community centers, friends' houses, or schools, as will be discussed throughout this chapter. And people who have access to the Internet at home do so under widely varying technical and social conditions.

One of the most important technical conditions is type of Internet connection. Overall, 82.3% of the households with home Internet access have a broadband connection (i.e., via cable or DSL [digital subscriber line]), with the remaining 17.7% connecting via a dial-up connection (see Table 1). Not surprisingly, though, type of connection varies by household income, educational level, and other factors. For example, among Native Americans, 71.9% of Internet households have a broadband connection, whereas among Asian Americans, 92% of Internet households use broadband. Combining the differential percentage of diverse households with Internet connections with the differential percentage of broadband use among Internet-connected households yields even starker disparities of total broadband access. Only 29.8% of Native Americans have broadband access compared with 69.1% of Asian Americans; only 18.4% of households with incomes between $5,000 and $10,000 have broadband access compared with 90.3% of families with incomes more than

TABLE 2
Percentage of U.S. Broadband Versus Dial-up Users Engaging in Online Activities in a Typical Day (and Who Have Ever Done the Activity)

Usage Categories	Typical Day (Ever)		
	All Internet Users	Broadband at Home Users	Dial-up at Home Users
Use a search engine	49 (89)	57 (94)	26 (80)
Check weather reports and forecasts	30 (80)	36 (84)	14 (75)
Get news online	39 (73)	47 (80)	18 (61)
Visit a state or local government website	13 (66)	16 (72)	4 (55)
Look online for information about the 2008 election	23 (55)	27 (62)	10 (37)
Watch a video on a video-sharing site	16 (52)	20 (60)	5 (29)
Look online for job information	6 (47)	6 (50)	4 (36)
Send instant messages	13 (40)	16 (44)	6 (38)
Read someone else's blog	11 (33)	15 (40)	3 (15)
Use a social networking site	13 (29)	16 (33)	7 (21)
Make a donation to charity online	1 (20)	2 (23)	0 (9)
Downloaded a podcast	3 (19)	4 (22)	1 (8)
Download or share files using peer-to-peer networks	3 (15)	3 (17)	2 (15)
Create or work on your own blog	5 (12)	6 (15)	3 (8)

Source. Horrigan (2008).

$150,000; and only 13.1% of households headed up by someone with an elementary school education have broadband access compared with 74.2% of those headed up by someone with a bachelor's degree.

Furthermore, research suggests that people who have home broadband connections use the Internet in markedly different ways than people who have home dial-up accounts (Horrigan, 2008; see Table 2). For example, 62% of adults with broadband access looked online for information about the 2008 election, whereas only 37% of those with home dial-up access did so. Although no similar comparative data are available for youth, one would imagine that the types of bandwidth-intensive applications that are considered especially valuable for young people, such as development and distribution of sophisticated multimedia content (Ito et al., in press), would be rarely carried out on a dial-up account, both because of the slower download and

TABLE 3
Number of Household Members Per Home Computer for Students in a California School District

	African Americans	Hispanics	Asians	Whites
Mean number of computers per household	1.56	1.22	2.48	2.27
Mean household size	2.63	4.61	3.46	2.18
Mean home user/computer ratio	1.68/1	3.78/1	1.40/1	0.96/1

upload times as well as the need to tie up a household telephone line for Internet use.

Although not as thoroughly investigated, other technical conditions surely shape home access to the Internet. For example, students per computer ratio was identified a decade ago as a key factor influencing how well computers are deployed for teaching and learning at schools (Becker, 2000a), yet household members per computer ratio has not yet been seriously analyzed as a factor affecting home computer use. Unpublished data from Grimes and Warschauer's (2008) recent study of a laptop program in an urban California district, combined with U.S. census reports of average family household size by race/ethnicity in the school district's county, indicate dramatic differences in household members per computer by racial/ethnic group, with White families having roughly one household member per computer and Hispanic families having nearly four people per computer (see Table 3). Such disparities will likely affect youth's opportunities to enjoy unpressured time to explore learning opportunities with computers.

According to analysis of CPS data by Fairlie (2007), African Americans and Latinos tend to own computers that are no older than those of Whites, yet they are more likely to report that their computers are not capable of Internet access. This could perhaps be explained by computers falling into disrepair or their owners simply lacking the means to purchase Internet access. As for other technical factors that likely affect computer use, such as differential access to software or peripherals, there are little data available.

Social factors are equally important as technical factors in shaping access. Influence from family members and friends can be critical in deciding whether and how to make use of computers and the Internet. A study of 1,000 people in San Diego found that social contact with other computer users was a key factor correlated with computer access (Regional Technology Alliance, 2001). As the study reports,

> Although most respondents stated that they know people who used computers, the digitally detached (those who do not have home personal computers, Internet access, or access to the Internet outside of the home) did not. And when compared with the impact of ethnicity, income, and education level, this sentiment—that they did not know others who used computers—is far more significant. (p. 12)

Youth today are not likely to be "digitally detached"; indeed, as will be discussed below, almost all youth use computers. However, with computer mastery depending heavily on social support, both from peers (see, e.g., Margolis, Estrella, Goode, Holme, & Nao, 2008) and family members (see, e.g., Barron, Martin, Takeuchi, & Fithian, 2009), many low-income or immigrant youth will have few friends or relatives who are sophisticated users of digital media. Conditions in the household (and neighborhood) such as relatively few computers, lesser degrees of broadband Internet access, fewer people with a college education, and fewer English speakers are likely to shape the kinds of experience youth have with digital media. We will return to this issue later in the chapter when we examine the diverse ways that youth use technology.

School Access

Given the ongoing discrepancies in home access to digital media, achieving equity of access at school takes on greater priority. There have been steady gains in this area, as more public schools of all types get more Internet-connected computers, but, once again, gaps persist.

The National Center for Educational Statistics gathered data on school access through surveys of about 85,000 schools administered nine times from 1994 to 2005, and presented these data in two issue briefs and five reports published between 1999 and 2006, each titled "Internet Access in U.S. Public Schools and Classrooms." The number of public school students per Internet-connected instructional computer in diverse types of schools was calculated for each year from 1998 to 2005, except for 2005 (Wells, Lewis, & Greene, 2006; see Table 4). In 1998, schools with 50% or more minority enrollment had 70.3% more students per Internet-connected computer than did schools with less than 6% minority enrollment (with ratios of 17.2:1 in high minority schools and 10.1:1 in low-minority schools). By 2005, that gap had fallen to 36.7% (with ratios of 4.1:1 in high-minority schools and 3.0:1 in low-minority schools). When examining access by rate of poverty, as defined by percent of students eligible for free or reduced-price lunch, the gap has almost closed. In 1998, schools with 75% or more of their students eligible for free or reduced-price lunch had 58.5% more students per Internet-connected computer than did schools with less than 35% of their students so eligible (with ratios of 16.8:1 in high-poverty schools and 10.1:1 in low-poverty schools), but in 2005 the gap was reduced to 5.3% (with ratios of 4.0:1 in high-poverty schools and 3.8:1 in low-poverty schools). The narrowing of these gaps is due in large part to government funding, with the federal e-Rate program providing about $2 billion per year for telecommunications and Internet access in schools, and many schools in low-income communities using Title I funding to purchase educational computers.

As in home environments, though, sociotechnical factors support or constrain use of computers and the Internet in schools, often in ways that heighten educational inequity. A comparative study of school technology use in high– and low–socioeconomic status (SES) communities found that the low-SES neighborhood

TABLE 4
Ratio of Public School Students to Instructional Computers With Internet Access, 1998–2005

	Years						
	1998	1999	2000	2001	2002	2003	2005
All public schools	12.1	9.1	6.6	5.4	4.8	4.4	3.8
Instructional level							
Elementary	13.6	10.6	7.8	6.1	5.2	4.9	4.1
Secondary	9.9	7.0	5.2	4.3	4.1	3.8	3.3
Locale							
City	14.1	11.4	8.2	5.9	5.5	5.0	4.2
Urban fringe	12.4	9.1	6.6	5.7	4.9	4.6	4.1
Town	12.2	8.2	6.2	5.0	4.4	4.1	3.4
Rural	8.6	6.6	5.0	4.6	4.0	3.8	3.0
Percentage minority enrollment							
<6	10.1	7.0	5.7	4.7	4.0	4.1	3.0
6–20	10.4	7.8	5.9	4.9	4.6	4.1	3.9
21–49	12.1	9.5	7.2	5.5	5.2	4.1	4.0
≥50	17.2	13.3	8.1	6.4	5.1	5.1	4.1
Percentage of students eligible for free or reduced-price lunch							
<35	10.6	7.6	6.0	4.9	4.6	4.2	3.8
35–49	10.9	9.0	6.3	5.2	4.5	4.4	3.4
50–74	15.8	10.0	7.2	5.6	4.7	4.4	3.6
≥75	16.8	16.8	9.1	6.8	5.5	5.1	4.0

Source. Wells, Lewis, and Greene (2006).

schools tended to have less stable teaching staff, administrative staff, and IT support staff, which made planning for technology use more difficult (Warschauer, Knobel, & Stone, 2004). As the study reported, the high-SES schools "tended to invest more in professional development, hiring full-time technical support staff and developing lines of communication among teachers, office staff, media specialists, technical staff, and administration that promoted robust digital networks." This, in turn, "encouraged more widespread teacher use of new technologies." In comparison, "the low-SES schools had achieved less success in creating the kinds of support networks that made technology workable" (p. 581). Because teachers in low-SES schools were less confident that the equipment they signed up for would actually work, and that if it did not work, they would have available timely technical support, they were more reluctant to rely on technology in their lesson plans.

In addition, even when teachers in low-SES schools had confidence in the hardware and software they were using, the sheer complexity of their instructional environments made it more difficult to use technology well. Challenges they faced included larger numbers of English language learners and at-risk students, larger numbers of students with limited computer experience, and greater pressure to increase test scores and adhere to policy mandates. As a teacher in a low-SES California high school said,

> Time is probably the biggest [problem]. Now it's even worse. Now that we're changing our curriculum big time to make it a standards-based curriculum . . . we really have to be efficient to cover the stuff that's in the standards in one academic quarter. There's not much time for other stuff . . . Before, if somebody pushed the computer lab, great. I could drop something that we were doing. It's not that critical, you know, it's an assignment we like, but, okay, let's drop it and let's go into the computer lab. And now we're dropping something that's on the [state] exam at the end of the year and our API score that goes in the [news] paper then could go down because of having more emphasis on computers. So, that is, to me, time is an even bigger obstacle now than it was the first couple of years. (Warschauer, Knobel, et al., 2004, p. 582)

Access From Other Locations

More than half of U.S. teenagers say they have accessed the Internet from libraries and at friends' houses (Lenhart, Arafeh, Smith, & Macgill, 2008; Lenhart, Madden, & Hitlin, 2005), though there is scant research documenting what teens do in these locations. In contrast, there is a wide body of research reporting youth's rich experiences with the Internet and other digital media at community centers (see, e.g., Hull & Katz, 2006; Kafai, Peppler, & Chapman, 2009), yet studies suggest that fewer than 1 in 10 youth report using the Internet at such centers, and almost no youth report such centers as the main place they go online (Lenhart et al., 2005). More discussion of how youth make use of technology at community centers and the role of such centers in addressing equity issues with technology will be discussed later in this paper.

USE

The most recent data on number of youth who use the Internet is provided by the Pew Internet & American Life Project, which interviewed 700 parent–child pairs by telephone and found that 89% of youth aged 12–17 years use the Internet at home and 94% use it from any location (Lenhart, Arafeh, et al., 2008; see Table 5). The 89% figure is considerably higher than the 70.3% Internet access rate for households with children reported by CPS (NTIA, 2008b) as well as the 78-80% rate of home Internet use for teenagers reported by the Kaiser Family Foundation (Roberts et al., 2005). The differences may be because of the later date of the Pew survey compared with the Kaiser Family Foundation survey, as well as due to differences in the methodology of the Pew survey compared with the CPS. Pew reports a 25% rate of response to its telephone survey, and although the responses are weighted for race and education, they are not weighted for income, and are thus likely to underrepresent low-income families who either lack a working telephone line or do not wish to be

TABLE 5
Percentage of U.S. Teenagers Who Use the Internet at Different Locations

	Anywhere	At Home	At School	At a Library
All teens	94	89	77	60
Gender				
Girls	95	91	76	59
Boys	93	86	78	60
Age (years)				
12–14	92	89	71	58
15–17	96	89	82	61
Race/ethnicity				
White	96	91	78	59
Black	92	80	83	69
Hispanic	87	85	69	53
Annual household income ($)				
<30,000	86	70	75	72
30,000–49,000	93	86	88	63
50,000–74,000	96	87	72	55
≥75,000	97	99	74	57

Source. Lenhart, Arafeh, Smith, and Macgill (2008).

interviewed for a research project. Most important, the parent–child pair interviews were only conducted in English, thus leaving out Spanish-speaking Latino families who are known to have markedly lower rates of Internet access than do English-speaking Latinos (Fairlie, 2007). Finally, the Pew survey reports on teenagers, whereas the NTIA discusses households with any age children younger than 18 years.

That being said, there is little disagreement that the strong majority of youth find a way to get online somewhere. Because African American and low-income youth use the Internet in public libraries at significantly higher rates than their White or higher income counterparts (see Table 5), it appears that the library serves, at least to some extent, as an alternative outlet for those without home Internet access.

It is also the case that youth spend a considerable amount of time online or otherwise using computers. The Kaiser Family Foundation reported the average amount of time spent on computers by age group as 37 minutes per day for 8- to 10-year-olds, 1 hour and 2 minutes per day for 11- to 14-year-olds, and 1 hour and 22 minutes per day for 15- to 18-year-olds. Their data, however, were collected in 2004, thus before the rapid growth of social network sites that have proven so popular among youth.

What, then, do youth do online? We will consider both out-of-school and in-school practices.

Out-of-School Use of Digital Media

A recent report, based on interviews and observations with hundreds of middle school– and high school–aged youth, provides an in-depth view of how young people in the United States use digital media today (Ito et al., in press). Ito and her colleagues identified two primary categories of online practices, which they label *friendship-driven* and *interest-driven*. Friendship-driven practices essentially involve hanging out with their peers online and either take the place of or complement other forms of youth socializing, such as hanging out at the mall. Youth usually hang out online with peers from school, but also occasionally with friends they meet through participation in sports, religious groups, or other offline activities. Hanging out rarely involves people that youth do not already know from their "real life," except in the case of groups who are especially marginalized, such as gays and lesbians, who may venture out more broadly online to seek social contacts. The principal tools for hanging out are social networks sites (specifically MySpace and Facebook), Instant Messaging, and computer and video games. Typical friendship-driven activities include chatting or flirting; uploading, downloading, or discussing music, images, and video; updating profiles and writing on friends' walls; and playing or discussing games.

The majority of youth do not move beyond friendship-driven activities, but the more creative and adventurous venture into interest-driven genres. As with friendship-driven activities, interest-driven activities typically involve communicating, game playing, and sharing of media. But in interest-driven genres, it is the specialized activity, interest, or niche identity that is the driving motivation, rather than merely socializing with local peers. This results in a much deeper and more sophisticated engagement with new media, and also brings participants into communication and collaboration with people of diverse ages and backgrounds around the world, rather than principally with their own local peers. As Ito et al. (in press) explain,

> Interest-driven practices are what youth describe as the domain of the geeks, freaks, musicians, artists, and dorks, the kids who are identified as smart, different, or creative, who generally exist at the margins of teen social worlds. Kids find a different network of peers and develop deep friendships through these interest-driven engagements, but in these cases the interests come first, and they structure the peer network and friendships, rather than vice versa. These are contexts where kids find relationships that center on their interests, hobbies, and career aspirations.

The Digital Youth Project identified two stages of interest-driven participation, which they label *messing around* and *geeking out*. Messing around involves early exploration of personal interests, wherein young people "begin to take an interest in and focus on the workings and content of the technology and media themselves, tinkering, exploring, and extending their understanding" (Ito et al., 2008, p. 20). Activities in this regard include searching for information online and experimenting with digital media production or more complex forms of gaming. Geeking out is the next stage, and involves "an intense commitment to or engagement with media or technology, often one particular media property, genre, or type of technology" and "learning to navigate esoteric domains of knowledge and practice and participating in communities that traffic in these forms of expertise" (Ito et al., 2008, p. 28). Examples of geeking out include creation and sharing of animated films that use computer game engines and footage (machinima); posting and critiquing of creative writing related to popular culture (fan fiction); development and publishing videos based on clips from anime series set to songs (anime music videos); writing and distribution of subtitles of foreign films or television programs, especially anime, within hours after the films or programs are released (fansubbing); and creation and posting of short dramatic or humorous films on YouTube (video production).

Learning and media theorists such as Gee (2003, 2004) and Jenkins (2009) make a compelling case that youth's engagement with new media provides vital learning experiences. However, their writings principally focus on youth who are engaged in interest-driven activities, and especially those who "geek out." Yet the Ito et al. (2008) study reports that only a small minority of youth move on to this geeking out stage, and also makes evident that access to additional technological and social resources, beyond a simple computer and Internet account, are critical to determining who moves on to these more sophisticated forms of media participation. Given the nature of geeking out activities, technological resources presumably include broadband access, relatively new computers with graphics and multimedia capacity, digital production software, and equipment such as digital cameras and camcorders. Social resources include a community that values and enables the sharing of media knowledge and interests, which can be found among family, friends, interest groups, or educational programs such as computer clubs and youth media centers.

Ito et al.'s (2008) study does not attempt to identify who, with the help of these resources, typically moves on to the geeking out stage, and who does not, but other studies have addressed this issue. One of the most compelling accounts is provided by Attewell and Winston (2003), who spent several months observing and interviewing two groups of computer users at home and school. The first group consisted of African American and Latino children aged 11 to 14 years who attended public middle school; most came from poor and working-class families, and all scored below grade level in reading. The second group consisted of school children from more affluent families who attended private schools.

The wealthier youths studied by Attewell and Winston (2003) were frequently engaged in interest-driven activities. For example, a White fourth-grade private school student named Zeke was a "political junky at ten years old" (p. 124). He spent his online time reading up on the Presidential inauguration, downloading video clips of politicians, and reading candidates' speeches. To assist his candidacy for class president—an office that was not sanctioned officially by the teachers at his school—Zeke found a free website that allowed visitors to construct quizzes and modified it to develop an online voting system. With the cooperation of his rival for office, he told each child in his class to visit the Web page for the voting system both to read the campaign speeches that he and his opponent posted and eventually to vote.

The low-SES group also pursued their interests, but in very different ways. Typical was Kadesha, a 13-year-old African American girl. Kadesha and her friends spent much of their online time checking out rappers and wrestlers (whom they referred to as their "husbands"), downloading their pictures as screensavers and pasting images into reports (Attewell & Winston, 2003, p. 117). They also went cyber-window shopping together, checking out everything from hot new sneakers to skateboards to Barbie dolls. The authors explained how Kadesha's ability to exploit the Internet was greatly restricted by her limited reading and writing skills:

> As image after image flashes by, . . . it becomes noticeable how rarely, how lightly, Kadesha settles on printed text. Like many of her friends, she reads far below grade level. So she energetically pursues images and sounds on the Web, but foregoes even news of her love interest if that requires her to read. (p. 117)

Of course working, with images and sounds can be an important part of geeking out, but Attewell and Winston's description makes clear that, in the case of Kadesha and many of her friends, engagement with multimedia was limited to consumption, not creation.

A study analyzing the 2003 CPS data provides statistical evidence of a home use divide (DeBell & Chapman, 2006). Among children in grades pre-K to 12 who used a computer at home, Whites were more likely than Blacks or Hispanics to use word processing, e-mail, multimedia, and spreadsheets or databases. These applications were also more widely used by children who lived in high-income families, those with well-educated parents, and those with English-speaking parents, as compared with children from low-income families or whose parents did not graduate high school or did not speak English. Further statistical evidence comes from a recent study of creative computing participation in two California middle schools, one in a high-SES community and one in a nearby low-SES community. Students at the high-SES school had greater access to diverse digital tools (including computers, the Internet, printers, scanners, handheld devices, digital cameras, and video cameras) and were much more likely to have both depth and breadth of experience in digital media production (Barron, Walter, Martin, & Schatz, in press).

Games

In the realm of games, research suggests that there are also important differences associated with SES and with gender as well. Andrews (2007, 2008a, 2008b) compared the game-playing practices of 133 students living in high-income neighborhoods and attending a private college preparatory school with those of 95 students living in low-income neighborhoods and attending a public Title I school (i.e., a school with more than 40% of its students qualifying for subsidized lunches). Methods included surveys, interviews, and *pile sorts*; the latter involved handing students game boxes and asking them to sort them into various categories, such as whether the students had seen or heard of them before, whether the games made sense to them, what categories of games they thought they were, and what kind of

TABLE 6
Types of Video Games Played by Students in Two U.S. High Schools

	Socioeconomic Status		Gender (%)	
	High (%)	Low (%)	Male (%)	Female (%)
Casual games	22.6	10	4.5	29.7
Computer games (noncasual)	19.4	4.5	14.3	7.7
Fantasy games	16.1	7.3	16.1	5.5
Sports games	19.4	44.5	47.3	15.4

Source. Andrews (2008b).

people they thought played them. Based on the pile sorts and interviews, Andrews developed four categories of games, which she called *casual* (e.g., puzzle, word, card games), *computer noncasual* (e.g., simulation and strategy games such as The Sims or Grand Theft Auto), *fantasy* (involving mythological or mystical characters, including both individual role-playing games for videogame consoles such as the Playstation and massively multiplayer role-playing games [MMORPG] for computers such as World of Warcraft), and *sports* (e.g., NBA Live).

When asking students to identify the top three games that students had played over the past year, Andrews found major differences both by SES and gender (see Table 6). High-SES students were more likely than their low-SES counterparts to play every genre of game except for sports. The difference was particularly pronounced in the noncasual computer games, which include strategy and simulation games believed to be important for learning purposes (see discussion in Gee, 2003). In the pile sorts and interviews, low-income students explained that these more involved computer games were "too complicated" or "too confusing" (Andrews, 2008b, p. 207). Boys were more likely than girls to play every kind of genre except casual games. And combined survey and interview data reported by Andrews suggests that by the end of her study, a large number of high-SES students were playing World of Warcraft, but that very few females or low-SES males were playing this or any other MMORPGs—an important finding given that the complex and highly collaborative nature of MMORPGs makes them ideal for advanced learning and literacy practices (see, e.g., Steinkuehler, 2007).

This last finding is associated with a broader trend identified by Andrews: high-SES students were far more likely than low-SES students to play games with other people, and males were similarly more likely than females to do so (see Table 7). For example, high-SES students were nearly five times as likely to play games with strangers online as low-SES students, and boys were more than eight times as likely as girls to do so. Boys were also more than six times as likely as girls to play with friends online. Finally, disparities were also noted in regards to students' related literacy practices outside the games. For example, males and high-SES students were more likely

TABLE 7
Differences in Social Patterns of Gaming Between Students in Two U.S. High Schools

	Socioeconomic Status		Gender	
	High (%)	Low (%)	Male (%)	Female (%)
With one friend online	37.0	16.2	24.6	4.1
With many friends online	39.1	17.6	26.3	4.1
With strangers online	50.0	10.3	26.3	3.1
With strangers in person (net café, etc.)	15.2	4.3	6.1	1.0
With one friend in person			57.9	6.7
With many friends in person			57.9	28.6
At a friend's house			58.6	37.8
At a relative's house			40.5	23.5
At a game store			17.2	2.0

Source. Andrews (2008b).

than girls or low-SES students to read magazines about games or access online *walk-throughs* (i.e., sites that provide written or illustrated instructions on optimal ways to beat a game or level).

Andrews's (2008b) findings are supported by other research on youth's experiences with game playing. The 2003 CPS data indicate that, among students who have home computers, boys, Whites, children from high-SES families, children with well-educated parents, and children whose parents speak English are all more likely to use computers for game playing than are girls, Blacks and Hispanics, children from low-SES families, or children whose parents did not graduate high school or do not speak English (DeBell & Chapman, 2006). The Pew Internet & American Life Project surveyed 1,102 12- to 17-year-olds in the United States from November 2007 through February 2008, and found that, compared with girls, boys were more likely to play videogames, play more game genres, play online games, and, by a nearly three to one margin, play massively multiplayer online games (Lenhart, Kahne, et al., 2008). The Pew study also found that of those who played games, Whites were slightly more likely than Blacks, and more than twice as likely as Hispanics, to play as part of a guild or group, and that Whites are much more likely than Blacks to play massively multiplayer online games. Other studies suggest that when males and females or high-SES and low-SES youth or Blacks and Whites play the same game, they may experience the game differently because of their background knowledge, belief systems, or sensitivity to racially or sexually charged material (see, e.g., Kafai, Heeter, Denner, & Sun, 2008; DeVane & Squire, 2008).

Community Centers and Libraries

A number of studies suggest that community technology centers and other informal digital media programs directed at youth can help overcome many of these disadvantages regarding access and use of technology. Center programs typically feature up-to-date equipment, high-speed Internet access, and access to digital peripherals such as printers or camcorders. Equally important, they provide a social context for learning with and through technology, whether in courses, workshops, drop-in clubhouse hours with mentors, or informal interaction with peers. A range of studies have reported the positive experiences for youth in such centers, whether working on digital storytelling (Hull & Katz, 2006; Hull & Nelson, 2005), media creation through use of programming languages (Peppler & Kafai, 2007), or digital documentaries on the social reality in local communities (Warschauer, 2003). Yet only 9% of youth indicate that they have ever gone online at a community center, youth center, or house of worship (Lenhart et al., 2005). There is thus much room to grow in giving youth opportunities for these media-rich experiences in informal settings.

Public libraries are much more widespread than community technology centers and are a much more common point of Internet access for youth (Lenhart, Kahne, et al., 2008). However, they usually lack the extensive technology instruction or expert mentorship available in community centers, and thus use of computers and the Internet in libraries is more differentiated by SES, as users must rely on their own unequal social resources for support. For example, a study in Philadelphia found that introduction of new technology in the city's libraries actually widened a divide in the quality of library use (Neuman & Celano, 2006). Children in low-income communities received little parent mentoring in libraries and, after technology was introduced, spent considerable time either waiting for computers to be free or playing computer-based games with little textual content; technology thus displaced reading for these children. In contrast, parents in middle-income communities "carefully orchestrated children's activities on the computer, much as they did with books" (Neuman & Celano, 2006, p. 193). Children in those communities thus spent more time on print-based computer applications, averaging 11 lines of print per application compared to 3.9 lines of print for the children in low-income communities. As a result, children in middle-income communities doubled the amount of time spent on reading following the introduction of technology, and the literacy gap between low- and high-income youth increased.

In-School Use

Discrepancies in whether youth use computers and the Internet at school are narrower than at home. This is seen in both the Pew study discussed above (Table 5) as well as in DeBell and Chapman's (2006) analysis of CPS data, which showed that 85% of Whites in grades pre-K to 12 in 2003 reported using a computer at school, compared with 80% of Hispanics and 82% of Blacks. However, the most important technology discrepancies in U.S. schools are not in whether computers and the

Internet are used, but for what purpose. The two widest U.S. studies (Becker, 2000c; Wenglinsky, 1998) on this topic were conducted in the 1990s. Both showed sharp disparities by race and SES in how new technologies were deployed for education.

Wenglinsky (1998) analyzed data from the 1996 National Assessment of Educational Progress (NAEP) to describe technology use patterns of 6,627 fourth graders and 7,146 eighth graders across the United States. Of all racial groups, African Americans were more likely to use computers at least once a week for mathematics at both the fourth grade and eighth grade level, likely because of the frequent use of remedial computer-based drills in math. Yet, paradoxically, a smaller percentage of African American students than any other racial group was taught math by teachers who had had professional development in technology use in the previous 5 years.

Wenglinsky (1998) divided up computer use into two broad categories. The first involved applying concepts or developing simulations to use them, activities that are both thought of as teaching higher order skills. The second involved drill and practice activities, which by nature focus on lower order skills. The study found that substantial differences by race/ethnicity, school lunch eligibility and/or type of school exist with regard to whether students reported their teachers primarily using these activities (see Table 8). Most notably, more than three times as many Asian students as Black students reported their teachers as primarily using simulations and applications in eighth grade mathematics instruction, whereas only about half as many Asians as Blacks reported their teachers primarily using drill and practice. Wenglinsky does not report how much of this differential was related to Asians and Blacks taking different types of math classes in eighth grade, and how much, if any, may have been independent of that.

In the second national study, Becker surveyed a representative sample of 4,000 teachers across the United States. His study confirmed the differences found by Wenglinsky, and found that they applied more generally rather than just in mathematics (Becker, 2000b, 2000c). He summarized the findings thus

> Computer use in low-SES schools often involved traditional practices and beliefs about student learning, whereas computer use in high-SES schools often reflected more constructivist and innovative teaching strategies. For example, teachers in low-SES schools were more likely than those in high-SES schools to use computers for "remediation of skills" and "mastering skills just taught" and to view computers as valuable for teaching students to work independently. In contrast, teachers in high-SES schools were more likely to use computers to teach students skills such as written expression, making presentations to an audience, and analyzing information. (Becker, 2000c, p. 55)

Becker also found that amount of usage by school SES differed by subject area. In mathematics and English—subjects in which, at least at that time, drill and practice software predominated—computers were used more frequently in low-SES schools than in high-SES schools. However, in science instruction, which tended to involve more simulations and applications, computers were used more frequently in high-SES schools.

Much has changed in computer capacity and usage in the time since these two national studies were conducted. Unfortunately, there have been no similar

TABLE 8
Percentage of U.S. Eighth Graders Whose Teachers Report Simulations/Applications and Drill/Practices as Primary Computer Uses

	Simulations/Applications	Drill/Practice
Total	27	34
Race/ethnicity		
Asian	43	27
Hispanic	31	30
White	25	34
Black	14	52
Family income		
School lunch ineligible	33	31
School lunch eligible	22	34
Type of school		
Private schools	30	10
Public schools	27	36

Source. Wenglinsky (1998).

large-scale quantitative studies done since to confirm or challenge these findings. However, a number of smaller case studies conducted by the first author of this chapter have examined the same issue with a narrower lens. These include a comparison of a high-SES private and low-SES public school in Hawaii, both known for good uses of educational technology (Warschauer, 2000); a study of 20 mathematics, science, English, and social studies teachers at three high-SES and five low-SES secondary schools in Southern California (Warschauer et al., 2004); and a multisite case study of 10 diverse schools in Maine and California with one-to-one laptop programs, in which all students in one or more classrooms were provided an individual computer (Warschauer, 2006). Taken as a whole, these studies have confirmed important discrepancies by student and school SES, while also suggesting that the specific nature of these discrepancies may be evolving over time. For example, Warschauer's studies have found differences not only in constructivist versus rote applications of technology, as suggested by Becker, but rather in different types of constructivist activity, with those occurring in low-SES schools more typically focused on what Scardamalia and Bereiter (2003) called *shallow* as opposed to *deep constructivism*. In these instances, individual or collaborative student-centered work, such as writing newsletters or finding information on Web pages, was often carried out with very limited goals, such as the development of most basic computer skills, rather than the achievement of deeper knowledge, understanding, or analysis through critical inquiry, as more frequently occurred in high-SES schools.

The California study carried out by Warschauer et al. (2004) illustrated in part why teachers in low-SES schools feel a need to emphasize computer skills. Surveys in the schools indicated that 99% of high-SES students had computers at home and 97% had Internet access, whereas in the low-SES schools, the rates were 84% for computer access and 72% for Internet access. In interviews, teachers made clear that they were keenly aware of these differences, and indeed, they tended to exaggerate them; while teachers in high-SES schools knew that almost all their students had computers and Internet access, teachers in low-SES schools believed that only a minority of their students had such access. However, whether their views were exaggerated or not, the teachers in low-SES schools were correct to assume that substantial numbers of their students did not come to school with the requisite access to have developed basic computer literacy. They thus used a disproportionate amount of time to teach hardware and software operations, and they were reluctant to assign homework, such as research papers or projects, that required out-of-school access to the Internet. In high-SES schools, teachers correctly assumed that they could forego instruction in basic hardware and software operations, because students had likely learned these at home—and that assigning more in-depth research that required out-of-school computer and Internet access would not unduly burden their students.

Finally, the more recent laptop study (Warschauer, 2006) carried with it both bad and good news as to the potential of these programs for alleviating inequity. On the one hand, laptop programs were more challenging to implement in low-SES schools for many of the reasons cited throughout this chapter. Students in low-SES schools had less home computer experience, and thus took more time to adapt to using laptops. Teachers in low-SES schools tended to be less experienced, and technical support infrastructures were not always as good. Parents were less able to guide their children on effective use of technology. Many low-SES schools were in high-crime neighborhoods, and there was thus more concern about laptops being stolen when taken home. And teachers had difficulty figuring out the best way to integrate laptops in situations where there were larger numbers of English language learners and students at below-basic reading levels. However, on the positive side, there were a number of schools and programs identified in the study that carried out exemplary technology-enhanced instruction with culturally and linguistically diverse low-SES students. In these programs, well-trained and highly committed teachers were able to use laptops to help raise low-SES students' test scores while simultaneously engaging students in more opportunities for critical inquiry and in-depth learning. Finally, because low-SES students were also less likely to have a computer at home, having take-home laptops allowed them to gain opportunities to learn technological skills that they might not have otherwise had.

One example given is Castle Middle School (pseudonym) in Maine, where about half the students are highly impoverished Whites from nearby housing projects, a quarter of the students are refugees and immigrants, and many of the remaining students are from middle-class and upper-middle-class suburbs. Previously, the school had been highly stratified, with seven distinct educational tracks, including one for the highly gifted, one for the accelerated (but not gifted), one for special education, one for non-English speakers, and several others calibrated by ability. In the 1990s, the school had rejected the tracking approach and developed an integrated program, with students of all abilities (including as many special education and ESL students as possible) grouped together into "houses" of about 60 learners with 4 main teachers. The entire curriculum for each house was organized into three 8- to 12-week theme-based learning expeditions, where students worked collaboratively on authentic projects. Though the reform had predated the school's one-to-one laptop program, the development of the laptop program amplified the success of the reform, by providing the best possible tool for students to collaboratively carry out research; present findings; and reflect on, critique, and document their work, while allowing for individual differences in knowledge and skills. As a result, Castle's combined test scores in writing, mathematics, and science have exceeded the state average, in spite of the school's large numbers of English learners and low-income students, and all students at the school are given a more equitable opportunity to excel than would be typical in such a stratified population.

OUTCOMES

Measuring outcomes is the most complex aspect of analyzing technology-enhanced learning, in part because the goals of teaching with technology are so diverse, and in part because many of those goals do not have clearly operationalized outcome measures. We begin by discussing academic outcomes, which are somewhat easier to measure, and then move on to examining 21st century learning skills.

Academic Outcomes

In testimony before a Congressional hearing on educational technology, Chris Dede (1995) wisely pointed out the problems with what he termed the "fire" metaphor of information technology. Just as a fire radiates heat, many people expect a computer to radiate learning. Unfortunately, that's not the case. Rather, as Dede noted, "information technologies are more like clothes; to get a benefit, you must make them a part of your personal space, tailored to your needs" (p. 10).

The most persuasive evidence that access to computers raises standard academic outcomes, such as grades, test scores, and graduation rates, comes from home rather than school settings. It may be the case that at home people are more able to make computers part of their personal space and tailor them to their needs.

One of the largest and most rigorous studies of the relationship of home computer use to test score outcomes in the United States was conducted by Beltran, Das, and Fairlie (in press). They used information from two national data sets to explore the causal relationship between computer ownership and high school graduation rates. The data sets were the Computer and Internet Use Supplements of the CPS for 2000–2003 (discussed above), and the National Longitudinal Survey of Youth 1997 (NLSY97). The latter involved hour-long interviews of a representative sample of 9,000 U.S. youth and their parents annually from 1997 to 2002, and also included the gathering of educational data such as youths' schooling history, performance on standardized tests, course of study, and the timing and types of degrees earned.

They found a dramatic relationship between home ownership of computers and high school graduation rate, with a differential in graduation between computer owners and nonowners of 24.3 percentage points according to the NLSY97 data and 16.6 percentage points according to the CPS data. They note that the 16.6 point difference attributed to owning a computer found in the CPS data is larger than the White/black difference (13.4 points) and comparable with the differences between teenagers who have college-educated and high school dropout fathers (19.7 percentage points), who have college-educated and high school dropout mothers (20.7 percentage points), and who live in families with incomes of \$75,000–\$100,000 versus \$20,000–30,000 (19.2 percentage points) found in the same data.

Part of the reason this differential is so high is that computer ownership correlates with a number of other factors associated with youth's educational achievement, such as family income, race, or parents' education. However, when controlling for these and other individual, parental, and family characteristics, it was found that teenagers who have access to home computers are 6 to 8 percentage points more likely to graduate from high school than teenagers who do not have home computers. They noted that this implies a larger difference in graduation probability than the difference from having a college graduate parent relative to a high school dropout parent. Using similar controls as above, the study found that having a computer was associated with a 0.22 point positive difference in grade point average (based on a 4-point grade scale, thus roughly 2/3 the value of a + or – grade), and a decline of 2.8 percentage points in the likelihood of being suspended from school. The study does not reveal the reasons for all these benefits, but the authors speculate that use of a home computer for schoolwork is a principal one, citing data from the CPS that 93.4% of youth with home computers use them for school assignments.

One question that Beltran et al. (in press) did not investigate was the possible differential effect of home technology access by SES or gender. Simply put—do the benefits of home computer use accrue equally across demographic groups? Using a previous iteration of the National Longitudinal Youth Survey (NLYS88), and based, this time, on standardized tests, Attewell and Battle (1999) found that, without other controls, having a home computer was correlated with about a 12% increase in both reading and math test scores. When SES and other factors were controlled for, having a home computer raised test scores by 3% to 5% of the average score. Most interestingly, they also studied the differential effect by SES, and found that, controlling for other possible factors, low-SES students who had home computers received much less benefit from them in raising their test scores than did high-SES students who had home computers. Table 9 shows the effect size on math and reading scores for high-SES students (1 standard deviation [*SD*] above the SES average), average-SES students, and low-SES students (1 *SD* below the SES average.) The numbers in the table indicate the changes in reading or math score measured in standard deviation units associated with 1 *SD* increase in home computer ownership by families at that SES level. They indicate that among families with home computers and controlling

TABLE 9
Size of Home Computer Effect by Socioeconomic Status (SES)

	Effect on Math Scores	Effect on Reading Scores
High SES	2.77	1.55
Average SES	1.69	1.08
Low SES	0.60	0.61

Source. Attewell and Battle (1999).

for all other possible variables, children from high-SES families compared with low-SES families receive more than four and a half times the benefit in increased math scores and more than two and a half times the benefit in increased reading scores. Substantial discrepancies further exist when comparing males versus females, Whites versus Hispanics, and Whites versus Blacks; in each case the former group achieved greater benefit on school test scores from having a home computer than did the latter group when controlling for other variables.

In sum, according to this study, not only were African Americans, Hispanics, and low-SES students less likely to have a home computer, but even when they *did* have a computer in this study, they, as well as females, received less academic benefit from having one compared to White, high-SES, and male students. Attewell and Battle's (1999) study provides no data as to why this may be the case. They speculate that it may be due to the *social envelope* (Giacquinta, Bauer, & Levin, 1993) that surrounds children's home use of computers and includes the kinds of technology resources (e.g., educational software) and social resources (scaffolding, modeling, and support from parents) that we have discussed earlier. They conclude that

> Home computing may generate another "Sesame Street effect" whereby an innovation that held great promise for poorer children to catch up educationally with more affluent children is in practice increasing the educational gap between affluent and poor, between boys and girls, and between ethnic minorities and Whites, even among those with access to the technology. (Attewell & Battle, 1999, p. 1)

Attewell and Battle's study is based on data that are some 20 years old, and the amount of home computers and the ways they are used have expanded dramatically during this time. However, a recent colloquium paper by three Duke economists reports similar results from a study in North Carolina, with race and SES strongly mediating the effect on academic achievement of home computer and Internet access (Clotfelter, Ladd, & Vigdor, 2008). If the Duke findings hold up under scrutiny of peer review, they are even more disheartening, as the study indicates an overall negative effect on math and reading test scores for low-SES and African American students with computer and Internet access, presumably because of "unproductive uses" of technology that "may not only crowd out productive computer time, but may also crowd out offline studying" (p. 37). As with the Philadelphia library study discussed above, such findings support the notion that the "social envelope" surrounding computer use is more important than computer access itself.

Academic Outcomes From School Use

Studies of academic outcomes from school use of technology are mixed (see, e.g., discussion in Kulik, 2003). Many studies are based on very small sample sizes and take place in schools or classrooms where individual educators are highly expert in particular uses of technology, and thus these studies may not be generalizable to other contexts.

Larger studies, though, suggest that the drill and practice activities favored in low-SES schools tend to be ineffective, whereas the uses of technology disproportionately used in high-SES schools achieve positive results. The best evidence of this discrepancy comes from Wenglinsky (2005), who analyzed data from the NAEP in 1996, 1998, and 2000. Overall, Wenglinsky found a consistently negative interaction between frequency of technology use and test score outcomes in mathematics (at both the fourth and eighth grade), science (at both the fourth and eighth grade), and reading (at the eighth grade; see Table 10). This appears to be because of the negative effects of drill and practice activities that are used predominately with low-SES students. In contrast, the more constructivist educational technology activities typically used with high-SES students were correlated with higher test score outcomes.

For example, in mathematics, Wenglinsky found that the use of simulations/applications in eighth grade and games in the fourth grade positively affected test scores, whereas drill and practice at the eighth grade negatively affected the scores. In science, games (fourth grade), word processing (fourth grade), simulations (fourth and eighth grade) and data analysis (fourth grade) all positively affected test scores. And in eighth grade reading, use of computers for writing activities positively affected test scores, but use of computers for grammar/punctuation or for reading activities (which usually involve drill or tutorials) negatively affected test scores. In each of the three subject areas, student SES was the strongest factor predicting whether technology use would be positively or negatively associated with test score outcomes.

More recent large-scale studies offer support for Wenglinsky's findings as to the ineffectiveness of drill-and-practice software. The U.S. Department of Education recently contracted a national experimental study to analyze the effects of educational software use on reading and mathematics test scores. A total of 16 software products, all of which involved tutorial and practice activities, were carefully selected from recommendations made by expert panels; 12 of the 16 have either received or been nominated to receive awards from trade associations, media, parents, and teachers. The comparative study involved 9,424 students taught by 428 teachers in 132 schools across the country (Dynarski et al., 2007). Teachers were randomly assigned to use 1 of 16 software products designed for teaching reading and math (treatment group) or not (control group) and students were given pre- and posttests during the first year of use. Overall, there was poor classroom implementation by teachers of the

TABLE 10
Links Between Technology Use and Test Scores

Subject: Grade	Test Scores
Math: Fourth grade	
Frequency of school computer use	–.06
Use: games	.03
Student SES	.59
Math: Eighth grade	
Frequency of school computer use	–.06
Use: simulations/applications	.04
Use: drill and practice	–.06
Student SES	.39
Science: Fourth grade	
Frequency of school computer use	–.21
Use: games	.07
Use: simulations	.08
Use: word processing	.09
Student SES	.25
Science: Eighth grade	
Frequency of school computer use	–.12
Use: data analysis	.04
Use: simulations	.07
Student SES	.54
Reading: Eighth grade	
Frequency of school computer use	–.02
Use: writing	.06
Use: grammar/punctuation	–.05
Use: reading	–.05

Source. Wenglinsky (2005).

software (as is apparently often the case with tutorial software; for another example, see Llosa & Slayton, 2009) and no significant effect of the software use on reading or math test scores of treatment students as compared with the control students even when fully implemented.

In contrast, more constructivist uses of technology are often found in one-to-one laptop schools, where students' daily access provides the opportunity for greater mastery of computers and their deployment for writing, research, collaboration, analysis, and publication (see Warschauer, 2006). Students in laptop programs are among the most frequent users of technology, and several recent studies show a positive correlation between laptop program participation and test score outcomes (see, e.g., Suhr, Hernandez, Grimes, & Warschauer, in press; Texas Center for Educational Research, 2008; additional studies reporting positive test score effects, though either without control groups or with self-selection into laptop groups, include Gulek & Demirtas, 2005; Silvernail, 2007; Jeroski, 2008).

Only one of these studies specifically investigated the differential impact of laptop program participation on test scores by SES or race. That study of sixth, seventh, and eighth graders found that being African American, Hispanic, or low-SES negatively affected how much test score benefit in reading and mathematics students received from participating in the laptop program, thus supporting findings from other studies on the differential academic benefits of computer access and use. It should be noted, however, that only in some combinations of grade level, subject, and demographic group did the differential effects rise to the level of statistical significance (Texas Center for Educational Research, 2008). In another study that looked at test score outcomes in both a high- and low-SES school, scores for laptop students actually fell in both schools during the first year of the laptop program implementation (compared with scores for non-laptop students elsewhere in the district), and then bounced back to equivalency with non-laptop students by the end of the second year (Grimes & Warschauer, 2008). The first-year dip was greater in the low-SES school compared with the high-SES school—consistent with the finding discussed earlier that laptop programs are more challenging in low-SES schools—but, at least in this study, the second-year test score rebound in the low-SES school was also greater.

The lack of positive results may be possibly explained by poor implementation of the programs, likely heightened by the fact that teachers were assigned to use a program rather than empowered to choose one themselves, as well as too early testing; technology-enhanced reform is somewhat disruptive (involving new equipment, new ways of teaching, etc.) and thus positive test score results may not appear until the second or subsequent year (see, e.g., Grimes & Warschauer, 2008).

Twenty-First Century Learning Skills

The types of standardized educational tests cited in the above section cover only a small fraction of the knowledge, skills, and attitudes youth need to learn to be successful in today's information society (see, e.g., Gee, 2003, 2004; Jenkins, 2009; Levy & Murnane, 2004, 2005). This suggests the limitations of overly emphasizing basic standards and standardized tests. In an era where everything standardized can be outsourced to another country, and the real premium thus comes from creativity and innovation (see, e.g., Levy & Murnane, 2004), it is counterproductive to focus all our educational efforts on teaching to basic standards.

The broader set of knowledge, skills, and attitudes that are needed for success in today's world are typically labeled *21st century skills*. A number of efforts have been made to define and categorize these skills (for an example, see North Central Regional Educational Laboratory & the Metiri Group, 2003; for an overview of international efforts, see Leu, Kinzer, Coiro, & Cammack, 2004), with the most widely recognized that of the Partnership for 21st Century Skills. The Partnership—a

FIGURE 3
Twenty-First Century Skills

Information, Media, and Technology Skills	• Information Literacy • Media Literacy • ICT Literacy
Learning and Innovation Skills	• Creativity and Innovation • Critical Thinking and Problem Solving • Communication and Collaboration
Life and Career Skills	• Flexibility and Adaptability • Initiative and Self-Direction • Social and Cross-Cultural Skills • Productivity and Accountability • Leadership and Responsibility

Source. Partnership for 21st Century Skills (2009).

broad coalition of educational groups (e.g., National Educational Association, the Association for Supervision and Curriculum Development, the American Association of School Librarians, Educational Testing Service), technology firms (e.g., Apple, Adobe, Cisco, Dell, Intel, Microsoft), and content/media providers (e.g., McGraw-Hill, Pearson, Scholastic, Lego, Blackboard, Sesame Workshop)—describes three sets of skills that are viewed as built on a foundation of core subjects (e.g., English, arts, mathematics, science, history) and interdisciplinary themes (e.g., global awareness, civic literacy). These three skills sets—in information, media, and technology; learning and innovation; and life and career areas (see Figure 3)—are intimately tied up with sophisticated uses of new digital media.

Though there is widespread agreement on the value of these types of skills in today's world, the lack of commonly accepted metrics for measuring achievement of these skills makes it difficult to assess the extent to which they are being mastered in diverse settings. Case study data provide some evidence, though they do not allow for quantifiable comparison.

In school settings, discussion of such skills frequently arises in research on one-to-one laptop schools. Many school laptop programs were established specifically with such skills in mind, and a substantive body of research suggests that well-implemented laptop programs facilitate acquisition of such skills. In Maine, for example, where there is a statewide middle school one-to-one program, more than one-third of students report using laptops from once a week to several times daily to gather data from multiple sources to solve problems, gather data about real-life problems, evaluate information obtained on the Internet, critically analyze data or graphs, solve complex problems by analyzing and evaluating information, explain problem-solving processes and thinking, and visually represent or investigate concepts (Silvernail, 2007). Interviews with teachers, students, and parents; observations of classrooms; and analysis of student work suggest that these kind of activities are yielding positive results for acquisition of 21st century learning skills in Maine and elsewhere (Warschauer, 2006).

There is insufficient data to assess any differential learning of 21st century skills in schools by race, SES, or gender, but the information discussed above about stratified uses of educational technology is worrisome in this regard. The types of drill and practice programs that are disproportionately used with low-SES students are generally geared narrowly on acquisition of academic content or basic literacy and numeracy skills, so it is unrealistic to assume that they would contribute much to broader 21st century skill development. In contrast, the simulations and applications used disproportionately by high-SES students are often deployed with precisely those skill sets in mind.

In addition, the general academic climate in schools substantially shapes how media are used, with technology serving to amplify schools' abilities to achieve their preexisting goals rather than to transform the goals themselves (see, e.g., Warschauer, 1999, 2000). Therefore, schools that are already focused on the kinds of information literacy, critical thinking, and self-direction associated with 21st century learning skills will find new media a powerful way to achieve these, whereas schools that do not have such a focus will not likely suddenly discover it through a diffusion of computers. Warschauer's (2006, 2007b) comparative study of information literacy practices in diverse schools in Maine provides a stark example of this. In a high-SES suburban school (grades 5–8), sophisticated information literacy practices are begun in the fifth grade, a year before students receive their laptops. Students attend library workshops where they learn to access diverse sources of information, critically evaluate them, and integrate the information appropriately into a variety of products. They are later taught to use computers to access information from online reference works and primary source documents. These skills are eventually put to use in challenging interdisciplinary research projects. In contrast, in a low-SES school in an impoverished rural community, no special training in information literacy is provided. Though the school subscribes to the same online database of reference works and primary sources, neither students nor teachers exhibit any awareness of it. Most typically, students grab the first source that comes up in a Google search, without much critical thought, and several of the schools' teachers expect little more. Students are observed spending substantial time cutting and pasting images and texts into low-level PowerPoint presentations. The study is careful to point out that these kinds of practices are not found at all low-SES schools, presenting a counterexample with more positive practices and results. However, based on analysis of data from 10 elementary and secondary schools in California and Maine, the study concluded that "teachers in high-income communities were more likely to expect and promote critical inquiry and information literacy than were teachers in low-income areas" (Warschauer, 2007b, p. 2537).

Out-of-School Development of 21st Century Skills

There is little doubt that intensive use of digital media in out-of-school environments can contribute to the development of 21st century learning skills. As at school, access to and use of new media are necessary but insufficient conditions for the development of such skills. But at least some youth, such as those that Ito and her colleagues found are "geeking out" in interest-driven activities, are undoubtedly mastering sophisticated skills in each of the three areas delineated in Figure 3. Consider the example of Max, a 14-year-old boy who hopes to be a director or filmmaker, and thus decides to set up a video-production company. Max and his friend produce humorous and dramatic videos that they post on YouTube, at least one of which has received 2 million views and more than 5,000 text comments and has been aired on ABC's *Good Morning America*. Max also regularly receives fan mail and has received offers to purchase some of his videos for online advertisements. Who would doubt that Max's use of digital media has enhanced the development of his media literacy, creativity and innovation, communication and collaboration, and initiative and self-direction?

One controversial area of home media use is game playing, with some concerned that it diverts time from more productive pursuits, and others arguing that such play is productive for learning new skills. One study attempted to assess the attitudes developed through game play via a survey of 2,500 Americans, principally business professionals, who included nongamers, moderate gamers, and frequent gamers (Beck & Wade, 2004). The survey methodology simply shows correlations without the power to demonstrate causation; nevertheless, the findings reveal some interesting differences. Among the young people surveyed, frequent gamers are more likely than nongamers to value risk taking, pay for performance, and connecting with the right people to get things done; they are also more likely to value the fate of the organization they work for (see Table 11).

There has long been a concern that girls are not gaining the same knowledge, skills, and attitudes about technology that boys are, because of differential uses of new media at home (see, e.g., AAUW Educational Foundation, 2000). The most recent research suggests that boys and girls spend about the same time on computers at home, but that boys spend substantially more time than girls playing computer games (Roberts et al., 2005). Boys may also be engaged more frequently in certain types of "geeking out" activities described by Ito et al. (2008) such as media production, though girls appear to be more engaged in other types of geeking out, such as those involving creative writing (M. Ito, personal communication). There are still substantial differences at the far end of the pipeline, both by gender and race, as measured by numbers of people who enter advanced study and careers in computer science, engineering, and related fields, to be discussed below.

Finally, we note that classes and informal instruction at computer media centers have been shown to be a particularly effective way of developing youth's 21st century learning skills. Hull and Katz (2006), for example, describe the case of Dara, a 13-year-old girl of Guatemalan heritage who attended an after-school media program

TABLE 11
Percentage of Young Nongamers, Moderate Gamers, and Frequent Gamers Who Agree With Statements

	Nongamers	Moderate Gamers	Frequent Gamers
The best rewards come to those that take risks	45.7	50.1	60.7
Taking measured risks is the best way to get ahead	52.9	54.6	59.7
I prefer pay and bonuses based on actual performance rather than a set salary	34.6	36.5	47.1
The best way to get things done is to connect with the right people	72.1	70.6	77.5
I really care about the fate of the organization I work for	39.4	41.0	44.0

Source. Beck and Wade (2004).

called DUSTY (Digital Underground Storytelling for Youth). Their article, based on field notes of Dara's participation at the center and at school over 2½ years and story scripts and digital stories created by Dara during this same time period, documents the changes that Dara experienced through participation at the center, both in terms of media skills mastered and in her sense of self and relationship to the world. As the authors explain,

> Not only did both Dara and Randy [a young adult at the school] master the technological skills necessary to create digital stories, but they also paid increasingly close attention to the technical aspects of language—to its sound, to genre, to its poetic dimensions, and to textual images as messages of another sort. And they masterfully combined image, sound, and text into powerful and personally meaningful multimedia narratives that also clearly and movingly spoke to others. These others included their DUSTY peers and friends as well as a larger social world that might not otherwise have listened to what they had to say; the fresh nature of the multimodality and multimedia itself appeared to lend their ideas both currency and urgency. (p. 70)

As a result of these new skills, Dara "found ways to reposition herself through digital storytelling both in relation to the people she loved and admired, and in relation to institutions, like school." She accomplished this "not only through her digital stories" but also through her "social relationships with DUSTY peers, mentors, and facilitators who helped build Dara's perception of herself as an expert digital storyteller and a skilled writer possessing technological savvy who could assist her friends in creating digital stories." In the end, a young girl who had a "meek and discontented school identity" thus became a "confident author and active community participant" (p. 61).

This is only one person, in one program, but it is illustrative of the changes that youth can experience when they master powerful symbolic systems to express themselves on issues of high personal and social relevance (see, e.g., Ito et al., 2008; Kafai et al., 2009). It also helps illuminate what agency vis-à-vis new media entails, and why community centers can be such important sites in the development of such agency. As discussed by Baumman and Briggs (1990, and cited in Hull & Katz, 2006), the "construction and assumption of authority" (p. 77) with use of texts rests on four factors: access, legitimacy, competence, and value. Community media centers can provide (a) access to the requisite technology and cultural artifacts for production of multimodal texts; (b) legitimization of learners' entry into the world of new media through the support of a community; (c) the means to acquire knowledge and competence with new media through instruction, apprenticeship, and practice; and (d) the valuing of youth's multimodal products by mentors, peers, and community members in everyday interaction and in special displays or performances. Although some youth are able to find this access, legitimacy, competence, and value through online activity in home environments, not all will be able to, and community centers thus provide a potentially rich alternative venue for the development of authority through media use and mastery.

FROM ACCESS TO OUTCOMES: THE COMPUTER SCIENCE PIPELINE

Although, for the purposes of this broad review, we have divided access, use, and outcomes into three sections, they are, of course, closely intertwined. To illustrate this interconnection we take, as an example, the *computer science pipeline*, that is, the long-term process through which children learn about computer science and pursue advanced study and careers in the field.

A fascinating examination of this pipeline comes from the Los Angeles Unified School District, where a research team at UCLA carried out an ethnographic study of computer science instruction at three Los Angeles area high schools from about 2001 to 2004 (Goode, Estrella, & Margolis, 2006; Margolis et al., 2008). The sites included a 98% Latino school in East Los Angeles, a magnet science school in a mostly White neighborhood but with 64% African American students, and a school in the wealthy hills near the Pacific Ocean with a mix of White (43%), African American (24%), Latino (24%), and Asian American students (8%). Many of the African American and Latino students at the two latter schools traveled long distances by bus to attend.

At the first two schools, which were predominately Latino and African American, no Advanced Placement (AP) classes in computer science were offered. The few computing courses that were offered focused principally on computer literacy and basic applications. A single exception was a programming class at the mostly Latino school taught by an instructor without formal training in the subject. The researchers noted that assignments focused on narrow input–output problems and trivia games, and that "none . . . features the problem solving and scientific reasoning that is the foundational knowledge of computer science" (Margolis et al., 2008, p. 32).

In contrast, the school in the wealthy neighborhood had an extensive computer curriculum, leading up to AP Computer Science. Nevertheless, the advanced computer classes, and especially the AP class, were themselves highly segregated, with the majority of students in them White males. The researchers noted that it was predominately White males who had the extensive experience with computers at home that gave them the confidence to take these elective courses, knowing that they would succeed and get good grades in them. These White male youth often owned more than one computer, had the financial resources to buy the latest hardware and software, and had extensive home experience in programming and gaming, supported by a network of friends and by their parents, many of whom worked in technology industries. These students were able to "play with their own computers, take them apart, put them back together, try out different software, and learn from friends who were doing the same." Many of them were "fully capable not of not only troubleshooting their computers but also building computers 'from scratch'" (Margolis et al., 2008, p. 80).

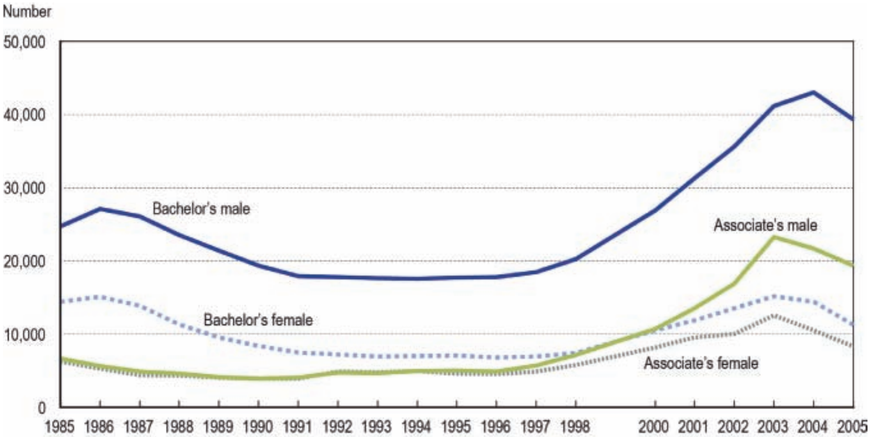
Few minorities or females at the school had had such extensive experience with computers at home and many were reluctant to take challenging computer science elective courses that could bring down their grade-point average and thus harm their chances at college admission. The handful of females and minority students who took advanced computer science courses often felt intimidated in class when White male "techies" (Margolis et al., p. 83) dominated discussions and made fun of the work of other students. As a result, very few females or minorities at any of three schools got the types of experiences that would lead them to careers in computer science.

These patterns are common beyond these three schools. In California, for example, though African Americans and Latinos made up 49% of the school population in 2004, they represented only 9% of those taking the AP computer science examination that year. Females, who similarly made up 49% of the California school population, represented only 18% of those taking the exam (Margolis et al., 2008). High achieving high school females are much less likely to have computer programming experience than are high achieving high school males (Barron, 2004).

Not surprisingly, women and minorities are underrepresented in college study of computer science and in careers in the field. And for women, the situation is steadily worsening over time. In 1985, women made up 49% of U.S. students receiving associate degrees in computer science and 37% of those receiving bachelor's degrees. By 2005, the percentages had dropped to 30% of associate degrees and only 22% of bachelor's degrees (National Science Foundation, 2008; see Figure 4).

As for race/ethnicity, the precipitous fall off is not so much over time, but rather according to degree level. African Americans received 14.4% of their associate's degrees in computer science, thus reflecting a strong interest among that population in pursuing this field. But they were only able to receive 11.6% of the bachelor's degrees, 7.7% of the master's degrees, and 2.6% of the doctoral degrees (National Science Foundation, 2009; see Table 12). For Latinos, the numbers are even worse. Thus Blacks and Latinos, who made up a total of more than a quarter of the U.S.

FIGURE 4
Bachelor's and Associate's Degrees Awarded in Computer Sciences, by Gender: 1985–2005



Source. National Science Foundation (2008).

population in 2006, received combined just 3.8% of the doctoral degrees awarded in computer science.

DISCUSSION: OVERCOMING THE NEW DIVIDE

Nearly all youth access computers and the Internet somewhere. Thus, what was considered the original *digital divide* is largely resolved, at least in the United States. Today the digital divide resides in differential ability to use new media to critically evaluate information, analyze, and interpret data, attack complex problems, test innovative solutions, manage multifaceted projects, collaborate with others in knowledge production, and communicate effectively to diverse audiences—in essence, to carry out the kinds of expert thinking and complex communication that are at the heart of the new economy (Levy & Murnane, 2004).

Whereas the first digital divide could be solved simply by providing a computer and an Internet connection, this digital divide presents a greater challenge. The above review suggests five steps that we can take to help meet this challenge, related to individual access, curriculum and instruction, standardized assessment, out-of-school media programs, and research.

Ensuring Regular and Flexible Access

First, we need to provide school-aged youth with individual access to computers with broadband Internet connections. Whereas a weekly trip to a school computer

Table 12
Degrees Received by U.S. Citizens and Permanent Residents in Computer Science by Race/Ethnicity in 2006

	Percentage			
	Whites	Blacks	Latinos	Asian
U.S. population age 18–24 years	61.4	14.2	17.5	4.3
Associate's degrees	63.1	14.4	9.8	5.0
Bachelor's degrees	60.7	11.6	7.2	11.0
Master's degrees	55.0	7.7	4.8	18.4
Doctoral degrees	70.3	2.6	1.2	21.8

Source. National Science Foundation (2009).

lab will suffice for learning basic computer literacy or for doing reading or math drills, regular and flexible access is required to facilitate the development of advanced knowledge production skills using technology—and, as this review has shown, such regular, flexible access is far from being achieved by many of today's youth, especially those who are already most at risk for failure at school. There are a variety of ways to increase individual access to computers, such as by providing tax credits to families who buy computers for school children at home. However, the simplest and most direct way is through one-to-one laptop programs at school. When such programs also allow students to bring laptops back and forth from home, the programs simultaneously address problems related to school access, home access, and school–home connections.

Until now, the large costs involved—for hardware, insurance, software, technical support, Internet connections, and professional development—made such programs very difficult to implement for financially strapped school districts. However, the continuing fall of laptop prices—with some small "netbook" computers already dropping near $200—will bring down hardware and insurance prices considerably, and the light weight of netbooks will increase their portability both from home to school and within the school environment. At the same time, the growth of free open source software and educational resources can facilitate the use of less powerful and inexpensive netbooks, while also substantially reducing the costs of both software and technical support. Finally, the generational shift of teachers, with more people now entering teaching careers with substantial computing experience, can result in improved pedagogical use of computers and thus further improve the cost–benefit ratio.

A crucial advantage of one-to-one laptop programs is that they potentially allow all students to work on technology-based research assignments and projects at home, thus helping extend learning time for all beyond the 30-hour school week, a major goal for educational improvement (Time, Learning, and Afterschool Task Force, 2007). However, this will be difficult to achieve if students lack broadband Internet access at home. A second policy implication then is the need for universal broadband. School districts and educational policymakers can consider a number of models for expanding home broadband access, from municipal wireless plans (for public access) to school district–private provider partnerships (for subsidized individual household access).

Teaching the Word and the World

Second, as shown throughout this review, access alone will not overcome inequity in use and outcomes. A critical step toward that end will be transforming teaching and learning in schools. Among school laptop programs, for example, the most successful in achieving positive outcomes for all students have clear and well-designed learning and literacy objectives; they are educational reform programs involving laptops, rather than technology programs per se (see discussion in Warschauer, 2006).

Whether in laptop programs or other instructional environments, schools need to move away from a narrow focus on teaching the basics to a broader approach that emphasizes *both* basic and 21st century skills, with the latter including the kinds of expert thinking and complex communication noted by Levy and Murnane (2004). Fortunately, excellent models exist on how to promote these broader skill sets in technology-intensive classrooms, whether in general (e.g., Kozma, 2003; Means, Penuel, & Padilla, 2001; Sandholtz, Ringstaff, & Dwyer, 1997; Wenglinsky, 2005) or in particular ways that address the needs of English language learners and at-risk students (e.g., Brown, Cummins, & Sayers, 2007; Cummins, 2008; Warschauer, 2006, 2007a; Warschauer, Grant, Del Real, & Rousseau, 2004).

Studies of highly successful instruction of at-risk learners in technology-intensive environments have led the first author of this chapter to summarize such a dual approach on basic and advanced skills as *teaching the word and the world* (Warschauer, 2006, 2007a). These studies revealed how Internet-connected computers can become powerful tools for helping learners understand and manipulate text, that is, to grasp the *word*. With appropriate instructional approaches, images and video can scaffold texts and provide clues for developing readers. Hypertext annotations can offer further scaffolding and encourage appropriate reading strategies. Graphic organizing software can help students analyze texts or plan their own writing. Word-processing software allows students to achieve a more iterative writing process. Computer-mediated classroom discussion provides students a way to communicate in written form, thus providing further opportunities for learners to notice others' written language and hone their own writing.

The same studies have shown Internet-connected computers to be a potent tool for bringing the wider *world* into the classroom and thus for both motivating and contextualizing literacy practices. Students can use the Internet to discover authentic reading material on almost any topic and be introduced to up-to-date information and perspectives from peoples and cultures across the globe. They can gather the resources needed to critically consider diverse social issues confronting their community, nation, or world. Students can then develop and publish high-quality products about these issues that can be shared with interlocutors or the public, whether in their community or internationally. And, through these products, students can not only learn about the world, but can also leave their mark on it.

One potent example of teaching both the word and the world is *Project Fresa* (the Strawberry Project), carried out among Spanish bilingual elementary school students in California (Warschauer, 2007a, Warschauer & Ware, 2008). Through conducting technology-enhanced research on the conditions of farm workers in neighboring strawberry fields, and assessing and acting on their findings in light of state and global contexts, Latino children involved in the project worked toward meeting basic standards while flexing their critical thinking and communication skills. Unfortunately, though, when one of the main teachers involved became an administrator, she was unsuccessful in getting other teachers to continue Project Fresa due to their fears that such theme-based projects would distract from their efforts to raise test scores (Warschauer & Ware, 2008).

Measuring What We Value

As seen from the above example, the main impediment to improving teaching with technology may not be lack of ideas on how to reform curriculum and instruction, but rather lack of incentive to do so, because of testing regimes that reward the achievement of only basic and not advanced skills. As Levy and Murnane (2005) explain,

> Perhaps the biggest potential obstacle to increasing students' mastery of Expert Thinking and Complex Communication are mandatory state tests (assessments) that emphasize recall of facts rather than these critical skills. Most states now require all students to complete mandatory assessments as part of programs to increase educational accountability. In many states, these assessments have been designed toward minimizing costs while producing numerical scores that can be compared across districts or over time. In a subject like history, a multiple-choice test is more likely to meet these criteria than an essay needed to demonstrate Complex Communication. In an area like math, a multiple-choice test is much less expensive to grade than an exam with open-ended responses that asks students to describe their thought processes—and to demonstrate the nature of their Expert Thinking. In the drive for educational accountability, teachers have strong incentives to teach to the test and so it is particularly important that we get the tests right. (p. 23)

If this is the case, how then can we begin "measuring what we value" rather than simply "valuing what we measure" (Hersh, 2006)? The answer is through an increase in performance assessment, including both the highly interpretive kinds performed by teachers at the class or school level (e.g., portfolio assessment) and the more standardized kinds that will entail development of new large-scale tests. An increase in the use of *classroom performance assessment* will necessitate providing teachers with the training, resources, administrative support, and incentives to reorient their instruction and evaluation of students to focus on the development of expert thinking.

An increase in the use of *standardized performance assessment* will require the funding and commitment to develop and deploy new tests that more accurately measure the kind of skills needed for the 21st century. And assessments of both types will need to involve use of digital media because paper-based examinations cannot accurately capture the learning that occurs through use of digital media (see a study by Russell & Plati, 2002, analysis of the issue by Silvernail, 2005, and discussion of *modal validity* by Luke, 2009).

A number of recent developments related to assessing 21st century skills are worth noting. First, Educational Testing Service (2009) has developed an information and communication technology literacy test called iSkills, which claims to assess "critical thinking in the digital environment" (para 3). Second, the Council for Aid to Education (2009), a nonprofit offshoot of Rand Corporation, has developed a College and Work Readiness Assessment that requires open-ended responses to constructed tasks to purportedly measure "an integrated set of critical thinking, analytic reasoning, problem solving, and written communication skills" (Council for Aid to Education, 2009, fourth paragraph). Third, the National Assessment Governing Board (2008), which sets policy for the NAEP, has contracted with WestEd to recommend the framework and test specifications for a Technological Literacy Assessment that will combine with the current tests of reading, writing, mathematics, and science to become part of the Nation's Report Card beginning in 2012. Fourth, the Programme for International Student Assessment has developed an Electronic Reading Assessment as part of its new battery of tests (Haldane, 2009). And, fifth, Cisco, Intel, and Microsoft have recently funded a team of researchers in Australia, the United States, and Hungary to develop and pilot ICT-based assessments of 21st century skills (Kozma, 2009).

Though none of these initiatives have resulted in replacement for the state-specific tests that carry so much weight under the No Child Left Behind Act, they are welcome efforts toward developing both the intellectual and policy framework for a new orientation toward standardized assessment. Without reform of assessment, teachers and administrators in public schools—and especially in low-SES schools that are so frequently subject to test score pressure—are unlikely to focus on the broad communication and thinking skills required for success in today's world.

Expanding Out-of-School Media Learning

Improved and more equal resources, instruction, and assessment in school cannot in and of themselves completely overcome unequal amounts of physical, human, and social capital in youths' out-of-school environments. This is especially so in relationship to learning of and with technology, so much of which occurs outside of school time. Providing more equal home access to individual computers and broadband Internet, as discussed above, will be one important step toward this end. Yet without enhancing social support for learning to use these resources, the mere provision of equipment could amplify the "Sesame Street effect" discussed earlier.

Initial evidence indicates that community technology centers and youth media programs can provide advanced technology learning experiences for youth. In particular, such centers and programs can help low-income youth transition from being passive consumers of media to more active and critical producers of digital content. Key to this transition is the social support found in such centers, where low-SES youth can gain access to the kinds of mentors, exemplars, peers with common interests, and pro-media production norms that many high-SES youth experience in their home environments. Yet only a small fraction of youth attends these programs. The expansion of funding for youth media programs and the enhanced integration of technology into extant after-school programs should thus be on the agenda of educational policymakers.

Unfortunately, the current economic climate may lead state or private funders to turn away from financing youth media centers. With home access to computers and the Internet slowly but steadily increasing, policymakers may also believe that youth will learn whatever they need to know about technology in home environments, under the myth that all youth are *digital natives* (see Prensky, 2001) who can effortlessly absorb advanced media skills on their own or from friends, thus making community centers redundant. We hope that this review has demonstrated the naïveté of such beliefs and the necessity of providing enhanced social support, such as that offered in youth media programs, if we are to seriously tackle inequity in use of technology and the outcomes associated with such use.

Researching Technology and Equity

Finally, what kind of research is required to increase our understanding of technology and equity? At a national level, the most thorough sources of statistical data on computer and Internet access and use have come from the federal government, either via the Current Population Surveys of the U.S. Census Bureau or from the National Center for Education Statistics of the Institute of Education Sciences (IES). Yet the gathering of data on this topic by both the Census Bureau and IES slowed down during the Bush administration, which downplayed the importance of the issue, and, as of this writing, has yet to be resumed by the Obama administration, which has had other pressing economic matters to address. A resumption of regular federal data gathering on this issue is vital.

Second, scholars addressing the relationship of technology and learning need to continue to include issues of equity, both in quantitative and qualitative studies. In quantitative research, the most widely cited studies on differential technology use in schools are now a decade old (e.g., Becker, 2000c; Wenglinsky, 1998). Quantitative research using more recent data sets can reveal how earlier trends may have persisted or changed course. In qualitative research, there has been a tendency by many scholars of technology and new literacies to examine model rather than typical practices, with the resultant publications presenting an idealized notion of how diverse groups might experience new technologies (see discussion in Warschauer, in press). Ethnographers would do well to replicate in the digital realm Heath's (1983) study of typical communication patterns and literacy practices in two diverse neighboring communities, as such comparative ethnography can richly portray the social contexts that shape inequity.

CONCLUSION

There is a widespread belief that the falling cost of computers and Internet access is rapidly narrowing a digital divide in U.S. society. However, as this review shows, gaps in home access to digital media are still substantial, and inequalities in technology usage and outcomes are even greater. Unfortunately, many of the measures most frequently used for analyzing technology-related access, use, and outcomes are insufficient. For example, phone-based surveys investigating home access disproportionately exclude marginalized groups, such as those who do not speak English or those who cannot afford phone service. And, most important, standardized tests, which have become the sine qua non for measuring school-based outcomes, do not even attempt to assess the broad thinking and learning skills associated with advanced uses of digital media.

Though technology-related access, use, and outcomes are difficult to measure, all available evidence suggests they are critically important factors in shaping social futures. As we rethink how to measure evidence of equitable resources, conditions, and outcomes of student learning, continued close attention to the role of technology in both school and out-of-school environments is urgently needed.

NOTES

Although technology and equity is an important issue facing youth throughout the world, space limitations prevent us from analyzing research on this issue from countries other than the United States. Those interested in international perspectives on technology access and use may wish to consult Warschauer (2003), Matuchniak and Warschauer (2010), Hull, Zacher, and Hibbert (2009), Plomp, Anderson, and Law (2009), or the Centre for Educational Research and Innovation (2009).

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