TECHNOLOGY AND QUALITY OF EDUCATION: DOES TECHNOLOGY HELP LOW-INCOME AND MINORITY STUDENTS IN THEIR ACADEMIC ACHIEVEMENTS?

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This study examines the equality of educational opportunities ("EEO") as it relates to the availability and usage of technology. It is generally held that technology is the key to bridging the achievement gap between students from disadvantaged and advantaged socioeconomic or ethnic groups. This study utilized a database constructed from the 1988-1992 National Education Longitudinal Study ("NELS") in order to investigate the relationships between the availability of technology to secondary-level students, socioeconomic ("SES") factors, and academic achievement overall.

With other relevant conditions constant, the findings suggest that: (1) when compared to their overall student peer group, racial-ethnic minorities and students of low socioeconomic status who did not have ready access to home computers lagged behind, but there was little difference when only school computer usage was considered; (2) for low SES and minority students, whether computer were used at home or schools had little effect on performance; (3) while there appears to be statistical variations in computer-related academic results, computer usage at school resulted in little increased value to overall achievement (a disappointing conclusion); (4) disadvantaged students generally appear to benefit less than their peers from using computers, whether at home or at school; and (5) statistically, the academic performance of disadvantaged students did not seem to have a correlation to computer usage or any other independent variables.

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I. INTRODUCTION

The assumption that technology injected directly into our existing educational system will uniformly benefit all children is overly simplistic and inaccurate. This study reasons that technology can improve academic performance only if it is delivered hand-in-hand with a learning-oriented school environment and changes in the traditional teaching model, which encourages learning and intellectual activity in children. Computer availability alone cannot narrow the achievement gap between different socioeconomic or ethnic groups; computer placement must be accompanied by efforts to increase the educational opportunities available to the students and to heighten student expectations of themselves.

II. BACKGROUND OF STUDY

A. Social Stratification of Education Technologies

The distribution of technology itself is in fact stratified.[1] Access to technology across socio-demographic categories is largely uneven because it is primarily determined by the resources available to individual schools, communities, and households.[2] Cutting-edge technology incurs high costs to establish, upgrade, and maintain. Both teachers and administrative staff need continuous training to keep abreast of technological changes.[3] Thus far, it is unclear whether or not online instruction could effectively lower costs to students since many institutions actually charge higher educational fees for online learning than for traditional instruction.[4] The increased cost to end-users only amplifies the already existing socioeconomic stratification of educational opportunities.

Further, it is unclear whether technology, even when available, actually benefits all students. There is little information available to support the concept that technology effectively reaches the most needy populations; perhaps it simply accommodates those groups of students who are already predisposed to take advantage of advanced learning

1. *See* Gary Orfield, *Federal Policy and College Opportunity: Refurbishing a Rusted Dream*, CHANGE, Mar./Apr. 1993, at 10–15.

2. *See* NAT'L TELECOMM & INFO. ADMIN., U.S. DEP'T OF COMMERCE, FALLING THROUGH THE NET: DEFINING THE DIGITAL DIVIDE 4 (1999) [hereinafter FALLING THROUGH THE NET]. *See also* LAWRENCE E. GLADIEUX & WALTON SCOTT SWAIL, THE COLLEGE BOARD, THE VIRTUAL UNIVERSITY & EDUCATIONAL OPPORTUNITY: ISSUES OF EQUITY & ACCESS FOR THE NEXT GENERATION (1999), *available at* http://www.ed.gov/officers/AC/ACSFA/april.pdf.

3. GLADIEUX & SWAIL, *supra* note 2, at 11; Kenneth C. Green, *Drawn to the Light, Burned by the Flame? Money, Technology & Distance Education*, 11 ED J. J-1, J-7 (1997).

4. WALTER S. BAER, ANNUAL REVIEW OF THE INSTITUTE FOR INFORMATION STUDIES, WILL THE INTERNET TRANSFORM HIGHER EDUCATION? (1998), *available at* http://www.rand.org/publications/RP/RP685.pdf.

opportunities.[5] Some point out the dangers that technology presents in terms of widening the educational gap so that "advantage magnifies advantage."[6] In this context, it is entirely possible that advantaged schools and individuals are simply more able to take advantage of cutting-edge technology whereas the needy groups benefit the least.

B. Disparities in Technological Resource Distribution

A recent national survey provides some evidence to support the skepticism regarding the actual effectiveness of computers in reducing the social stratification among students. Based on a 1999 household survey, the U.S. Department of Commerce reported clear patterns of uneven distribution in terms of technological access. This included access to computers, WebTV, the Internet, and E-mail. Income is clearly a determinant of access to the Internet and other advanced communications technologies; high-income families (those with incomes above $75,000) demonstrate far higher levels of Internet access than those observed in the low-income categories (those with incomes below $14,000). These gaps are wide both in homes and schools, suggesting that computer availability in schools does not sufficiently remedy the socioeconomic disparity issue.[7]

Race and ethnicity are also important factors in examining the stratification of Internet access.[8] African American and Hispanic groups are less likely to have Internet access at home than Caucasians or Asian-Pacific Islanders, though it bears mentioning that the access gap outside the homes is significantly narrower. Remarkably, the access gap in homes has been growing in recent years, particularly in relation to family income.[9]

Schools and other public institutions are expected to bridge this gap, but so far have had limited success. The U.S. Department of Education report suggests that the availability of technology to students and schools

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5. STEPHEN R. BARLEY, CTR. FOR WORK, TECH., AND ORG., INDUS. ENG'G & ENG'G MGMT., COMPETENCE WITHOUT CREDENTIALS: THE PROMISE AND POTENTIAL PROBLEMS OF COMPUTER-BASED DISTANCE EDUCATION (1999), *available at* http://www.ed.gov/pubs/competence/section2.html. *See generally* Nancy Hoffman, *Shifting Gears: How to Get Results with Affirmative Action*, CHANGE, Mar./Apr. 1993, at 30–34.

6. *See, e.g.,* ELAINE SEYMOUR & NANCY M. HEWITT, TALK ABOUT LEAVING: WHY UNDERGRADUATES LEAVE THE SCIENCES (1997).

7. *See* Walter W. McMahon, *Efficiency & Equity Criteria for Educational Budgeting & Finance*, *in* FINANCING EDUCATION: OVERCOMING INEFFICIENCY & INEQUITY 2 (Walter W. McMahon & Terry G. Geske eds., 1982).

8. *See generally* Robert H. Ennis, *Equality of Educational Opportunity*, *in* 26 EDUC. THEORY 3 (Winter 1976); WILLIAM B. DORFMAN, NAT'L CTR. FOR EDUC. STATISTICS, EDUCATIONAL OPPORTUNITY: THE CONCEPT, ITS MEASUREMENT & APPLICATION 34–64 (1978).

9. FALLING THROUGH THE NET, *supra* note 2, at 40; *see also Sex Differences in Choice of College Science Majors*, 25 AM. EDUC. RES. J. 593, 593–614 (1988); NAT'L SCI. FOUND., WOMEN, MINORITIES, & PERSONS WITH DISABILITIES IN SCIENCE AND ENGINEERING 1998, *available at* http://www.nsf.gov/sbe/srs/nsf99338/pdfstart.htm (Feb. 1999).

remains uneven across SES borders.[10] The report examined access in terms of schools connected to the Internet, the percentage of instructional rooms equipped with Internet access, and the ratio of students to computers used in educational applications. For each of these measures, schools with large percentages of low-income students fared very poorly. The good news is that this poor performance substantially improved during the period from 1994 through 1999, as revealed by a narrower gap between low-income and high-income schools. Similar and substantial gaps among different socioeconomic levels can be seen in relation to non-Internet educational technology.[11] Given limited resources, schools with large numbers of low-income students are hard-pressed to provide adequate equipment and programs for their pupils to effectively access technology as part of their educations. Recent national school survey data shows that the progress in tightening these technology access gaps is uneven, with significantly lower rates for schools with large numbers of minority students and students from low SES standing.

C. Processes in Using Technologies

The manner in which technology is used is differentiated by school settings and student backgrounds. As "advantage magnifies advantage," rapidly changing technologies applied in the educational context may even widen the existing gaps in educational quality across racial and socioeconomic categories.[12] The U.S. Department of Education's survey for the year 2000[13] found substantial differences between affluent and poor schools in *the processes* that teachers use to instruct students on using computers and the Internet. Compared with their counterparts in affluent schools, teachers and students in poor schools are more likely to use computers for practice drills and less likely to use them for actual research.

Disadvantaged students are also more likely to attend less challenging computer-related courses.[14] Those students are more likely

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10. *See* NAT'L CTR. FOR EDUC. STATISTICS, COMPUTER ACCESS IN PUBLIC SCHOOLS & CLASSROOMS: 1994-2000 (2001) [hereinafter COMPUTER ACCESS], *available at* http://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2001071; NAT'L CTR. FOR EDUC. STATISTICS, INTERNET ACCESS IN PUBLIC SCHOOLS & CLASSROOMS: 1994-1998 (1999) [hereinafter INTERNET ACCESS], *available at* http://nces.ed.gov/pubs99/1999017.pdf.

11. *See* NAT'L CTR. FOR EDUC. STATISTICS, CONDITIONS OF EDUCATION 1999: RACIAL AND ETHNIC DISTRIBUTION OF ELEMENTARY AND SECONDARY STUDENTS, *available at* http://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=1999022 (last visited Mar. 18, 2000).

12. *See* GLADIEUX & SWAIL, *supra* note 2; SAMUEL S. PERG & SUSAN T. HILL, NAT'L CTR. FOR EDUC. STATISTICS, RESEARCH AND DEVELOPMENT REPORT: UNDERSTANDING RACIAL-ETHNIC DIFFERENCES IN SECONDARY SCHOOL SCIENCE AND MATHEMATICS ACHIEVEMENT (Feb. 1995); Mark Warshauner, *Technology and School Reform: A View from Both Sides of the Tracks*, 8 EDUC. POL'Y ANALYSIS ARCHIVES 1 (Jan. 7, 2000), *at* http://olam.ed.asu.edu/epaa/v8n4.html.

13. NAT'L CTR. FOR EDUC. STATISTICS, TEACHER USE OF COMPUTERS AND THE INTERNET IN PUBLIC SCHOOLS (Apr. 2000).

to be taught general computer literacy than how to use computers to enhance learning in key subject areas. Moreover, when exposed to computers as a subject area, high SES students are more likely to engage in computer programming (as opposed to lower-level computer-related tasks) than low SES students. Generally, high SES students are more likely to use computers primarily for "higher-order or mixed activities" (rather than practice drills or other skill-building and knowledge-acquisition activities) than are low SES students of the same grade levels. Due to such higher-order computer activities, high SES students disproportionately receive better opportunities for learning than do poor and minority students.[15] The disparities in the mode of computer usage reveal a form of inequity at least as important as the disparities in computer availability and accessibility.[16]

Significantly, access to technologies at home has a great deal to do with *how* technologies are learned in school. Students whose families provide ready access to computers are likely to apply advanced computer skills at school, such as analyzing complex systems and engaging in college-oriented academic work. In contrast, students who have no experience with computers at home often are placed in computer courses that emphasize routine skill-learning or job-oriented training.[17] Revealing the ironic relationship of technology to equitable education, one study compared an elite private school and an impoverished public school.[18] While reforms introduced at the two schools appeared similar on the surface, underlying differences in resources and expectations reinforced patterns by which the two schools channel students into academic, college-oriented futures as opposed to vocation-focused workplaces. Thus, increased use of technology in the schools seemed to heighten distinctions among students based on class and race.[19]

Teaching and learning conditions, expectations, and policies differed dramatically between the two studied schools. The public high school's reforms, including those focused on technology usage, were geared toward better preparing students for the workforce.[20] Teachers worked to help students develop the types of technological literacy and human

14. *See* NAT'L CTR. FOR EDUC. STATISTICS, NATIONAL EDUC. LONGITUDINAL STUDY: 88/2000 FOURTH FOLLOW-UP: AN OVERVIEW (2000) [hereinafter NELS: 88/2000 FOURTH FOLLOW-UP].

15. *See* HAROLD WENGLINSKY, EDUCATIONAL TESTING SERVICE, DOES IT COMPUTE? THE RELATIONSHIP BETWEEN EDUCATIONAL TECHNOLOGY AND STUDENT ACHIEVEMENT IN MATHEMATICS 2–40 (1998) *available at* ftp://ftp.ets.org/pub/res/technolog.pdf. S*ee generally* ELLWOOD P. CUBBERLEY, SCHOOL FUNDS AND THEIR APPORTIONMENT (1905).

16. *See* NAT'L CTR. FOR EDUC. STATISTICS, REPORT IN BRIEF: NAEP 1996 TRENDS IN ACADEMIC PROGRESS 1–22 (2000), *available at* http://nces.ed.gov/nationsreportcard/pdf/main1996/97985r.pdf.

17. WARSCHAUER, *supra* note 12. *See also* WENGLINSKY, supra note 15, at 2–40 .

18. *See* Warschauer, *supra* note 12.

19. *Id.*

20. *Id. See also* Mark Windschitl & Kurt Sahl, *Tracing Teachers' Use of Technology in a Laptop Computer School: The Interplay of Teacher Beliefs, Social Dynamics, and Institutional Culture*, 39 AM. EDUC. RES. J. 165 (2002).

relations skills that might be needed in the workplace, without putting great emphasis on academic content. In contrast, private school students worked on Web page development as a part-time paid job, rather than as part of their academic course load. The private school was specifically designed to produce high achievers for prestigious universities who would eventually go on to become the academic and professional leaders of tomorrow. In biology classes, for example, students typically used computers to perform research and analyses similar to those that a university researcher might perform.[21]

D. Individual Factors and Educational Computer Use

Individual psychological and behavioral patterns are potentially confounding factors in regard to the effect of technological application on the quality of education. Compared to Caucasian and Asian-Pacific Islander students, African American and Hispanic children were less motivated to participate in computer-based programs because they perceived computers and mathematics to be overwhelmingly complicated.[22] Children who are motivated toward intellectual growth can learn tremendously as they interact with the vast amounts of information presented by such computer and network technologies. In contrast, children who lack such motivation may also spend a great deal of time on computers and the Internet, but only end up with addictions to electronic games, pornography, and other potentially destructive material. In short, access to technology per se may either reduce or widen gaps between advantaged and disadvantaged students depending on how programs and instructional strategies are developed to use specific technologies in a wise fashion.[23]

III. CONCEPTS/RESEARCH QUESTIONS

There are two constructs to keep in mind when examining the impact of technology on equalized educational opportunity: (1) *technically generic benefits* and (2) *socially differentiated benefits.* The former refers to the idealized concept of information technology and its universal capability to consistently benefit any student; the latter suggests that the effectiveness of technology in the classroom varies in regard to its application and the social grouping of its audience. This system of dual benefits is the central tenet of this study.

21. *See* Sarah Michaels et al., *Whose Computer is it Anyway?*, 17 SCI. FOR THE PEOPLE 36, 43–44 (1985); Jeannie Oakes, *Opportunities, Achievement, and Choice: Women and Minority Students in Science & Mathematics*, 16 REV. OF RES. IN EDUC. 153 (1990).

22. *See* NAT'L SCI. FOUND., WOMEN, MINORITIES, & PERSONS WITH DISABILITIES IN SCI. & ENG'G (1996), *available at* http://www.nsf.gov/sbe/srs/nsf96311/start.htm.

23. *See* CAROL KIMBLE, MID-CONTINENT REGIONAL EDUCATIONAL LABORATORY, THE IMPACT OF TECHNOLOGY ON LEARNING: MAKING SENSE OF THE RESEARCH 3–4 (May 1999), *available at* http://www.mcrel.org/PDF/PolicyBriefs/5983PI_PBImpactTechnology.pdf.

Recent dramatic advances in technology have brought with them a promise of allowing educators to realize the idea of the EEO. Many believe that through the proper placement of high technology, minority, and underprivileged students can receive an education of the same quality as their more fortunate peers.[24] New computing and networking technologies have the potential to bring knowledge-building and communication tools into the reach of disadvantaged students and provide them with more individualized learning opportunities.

Under the concept of "technically generic benefit," using technology in education, including online instruction and interactive computer-based systems, allows learners ready access to vast stores of information and offers the potential to accommodate individual learning styles, needs, or abilities. Drawing heavily from a constructivist model, technology is also used as a catalyst for changes in pedagogic methodology. Those changes include the transition from large classes to small group instruction, from teacher-centered education to student-centered learning, and from uniform curricula to customized curricula according to individual needs.[25]

New computing technologies are intended to empower historically disadvantaged groups by giving them greater access to better learning tools. Such intentions are at least particularly supported by existing studies.[26] The theory of socially differentiated benefits was based on research demonstrating that low-income and minority students, the same historically disadvantaged groups mentioned earlier, do not equally benefit from the availability of advanced technology as compared to their more fortunate peers.[27] Disadvantaged children tend to utilize computers for routine learning activities rather than for intellectually demanding applications.

The social conditions into which advanced technologies are placed largely influences whether they serve to narrow the SES gap or widen it even further.[28] An analysis of the integration of technology into instruction shows that traditional patterns of classroom organization might very well be impermeable to change, even with the introduction of

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24. *See generally* LUTZ BERKNER & C. DENNIS CARROLL, NAT'L CTR. FOR EDUC. STATISTICS, STATISTICAL ANALYSIS REPORT: ACCESS TO POSTSECONDARY EDUCATION FOR THE 1992 HIGH SCHOOL GRADUATES (Oct. 1997).

25. *See* Valerie E. Lee & Anthony S. Bryk, *Curriculum Tracking as Mediating the Social Distribution of High School Achievement*, 61 SOC. OF EDUC. 378, 381–95 (1988).

26. FALLING THROUGH THE NET, *supra* note 2.

27. Kern Alexander, *Concepts of Equity*, *in* FINANCING EDUCATION: OVERCOMING INEFFICIENCY & INEQUITY, *supra* note 7, at 193; Deborah A. Verstegen & Terry Whitney, *From Courthouses to Schoolhouses: Emerging Judicial Theories of Adequacy and Equity*, 11 EDUC. POL'Y 330 (1997); Debra Viadero, *The Electronic Gender Gap,* Education Week on the Web, *at* http://www.edweek.com/ew/1994/15gender.h14 (Dec. 14, 1994); HAROLD WENGLINSKY, EDUC. TESTING SERV., DOES IT COMPUTE? THE RELATIONSHIP BETWEEN EDUCATIONAL TECHNOLOGY AND STUDENT ACHIEVEMENT IN MATHEMATICS, *at* http://www.icoe.k12.ca.us/pdf/technology.pdf (Sept. 1998).

28. NAT'L SCI. BD., NAT'L SCI. FOUND., SCI. & ENG'G INDICATORS (1998).

large numbers of computers into schools.[29] Such research suggests that the mere presence of computers, even when implemented in instruction, does not necessarily result in the enhancement of learning opportunities. In fact, the existence of these technologies may lead to their socially stratified use, which only reinforces the traditional segregations among SES groups in education, confirming some views of the traditional role of the school system in terms of social reproduction.[30]

Little research has been conducted to scrutinize and identify the conditions under which educational technologies benefit disadvantaged children's learning and ultimately reduce the gap in result-oriented educational quality.[31] Among many things influential to educational outcomes, school resources, curricula, teacher expectations, home computer ownership, and the individual educational aspirations of each child are probably the more salient factors that interact with technology and jointly determine the academic performance. This study, for example, focuses on how access to computer-related technologies interacts with school environments and children's psycho-behavioral attributes to enhance academic learning among minority and low-income children.

Hypothetically, computer access may have limited affect on academic achievement. Such access may interact with race and SES factors in relation to academic achievement among Caucasians, Asian-Pacific Islanders, and high SES students to a greater extent than it does in relation to other minority students. Home computer usage also interacts with access to computers at school in regard to academic performance. Thus, having access both at home and at school may relate to high performance to an extent greater than an additive effect of the two variables. Without home computer use, however, the relationship between school access and academic performance may not be substantial.

Whether computer access relates to academic achievement may depend on school resources, curricula, instruction, and teacher expectations.[32] Only under conditions of well-resourced and academically-oriented school settings, strong academic programs, and high expectations by teachers do students' achievements positively relate to computer access. Furthermore, computer access interacts with

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29. *See* JOHN E. COONS ET AL., PRIVATE WEALTH AND PUBLIC EDUCATION (1970); Bertram Bruce, *Taking Control of Educational Technology*, 17 SCIENCE FOR THE PEOPLE 37, 37–40 (1985).

30. *See* J. D. ANDERSON, AMERICAN SCHOOL REFORM AND EDUCATIONAL POLICY (1997); Sophia Catsambis, *The Path to Math: Gender and Racial-Ethnic Differences in Mathematics Participation from Middle School to High School*, 67 SOC. EDUC. 199 (1994); J. C. COLEMAN, EQUALITY & ACHIEVEMENT IN EDUCATION (1990).

31. David A. Hamburg, *Science and Technology in a World Transformed*, 224 SCI. 943, 945 (1984); *see also* Dexter A. Magers, *Two Tests of Equity Under Impact Aid Public Law 81-874*, 3 J. EDUC. FIN. 124 (1977).

32. *See* Min Liu, *The Effects of HyperCard Programming on Teacher Education Students' Problem-Solving Ability and Computer Anxiety*, 29 J. OF RES. COMPUTING IN EDUC. 248, 249 (1997).

students' psycho-behavioral characteristics in that it positively relates to academic achievement only among students who are intellectually motivated and who take advanced courses.[33]

Along with the notion of outcome-focused education quality, academic performance is a salient factor in analyzing the influence of educational technology. In particular, a standardized cognitive test administered to a nationally representative sample of high school students offers measure of outcome-oriented EEO comparable across geographic and socio-demographic categories. Because educational outcomes are influenced by many factors, in comparing outcomes in relation to the focal predictors in this study (access to technologies, race, and SES), other critically important influences must be considered simultaneously. Such factors include curricula and instruction, school environment, teacher expectations, parental support, and children's motivation and learning behavior, to name a few. Statistically controlling for such key predictors of academic achievement, the proposed analysis focuses on the relationship between access to technology and academic performance, all with other major conditions being equal. Specifically, this study attempts to address the following issues (all statements are made *ceteris paribus*):

- Issue 1: The Access Gaps: How does high school students' access to and use of computers vary by race-ethnicity and SES?
- Issue 2: Generic Benefits: How does computer access at school and home relate to high school students' academic achievement?
- Issue 3: Differential Benefits: Does the relationship between computer access and academic achievement differ across racial-ethnic and SES subgroups?
- Issue 4: The Gap Reduction Effect: Without access to computers at home, does school computer access relate to higher academic performance of minority and low SES students?
- Issue 5: Technology-School Interaction Effects: How do computer access and school experiences (instruction, curricula, school environment, and teacher expectations) jointly relate to academic performance and reducing or widening the gaps associated with race-ethnicity and SES?
- Issue 6: Technology-Individual Interaction Effects: How do computer access and individual psycho-behavioral attributes (motivation to learn, educational and occupational aspiration, and learning behavior) jointly relate to academic performance, and reducing or widening the gaps associated with race-ethnicity and SES?

33. *See* Min Liu, *The Effect of Hypermedia Authoring on Elementary School Students' Creative Thinking*, 19 J. EDUC. COMPUTING RES. 27 (1998).

IV. DATA SOURCE AND METHODOLOGY

This study draws upon data from the National Education Longitudinal Study of 1988-1992 ("NELS") in the analysis. NELS is a general-purpose national survey for studying secondary education which contains extensive information about secondary school student backgrounds and school experiences.[34] NELS began its base year data collection in 1988 when the sampled students were in eighth grade. Follow-Up surveys were conducted in 1990, 1992, and 1994, and the last wave of data collection was underway in 2000.[35] The multi-level, stratified probability student sample, with certain adjustments, represents the 1988 sample of eighth grade students.[36] In addition to the students, their parents, teachers, and school administrators were also surveyed. Transcript data on the students' course work and administrative data on the curricula offered by the schools were included in the survey as well. The unit response rates for the panel data were sufficiently high (see Appendix A for missing cases by race-ethnicity and SES). We used base year through the second follow-up panel data of public high school students who did not change school between grades ten and twelve.

A. Variables in the Analysis

The extracted data were edited and/or re-scaled. Appendix B presents descriptive statistics of the variables used in the analysis. "Student academic performance" measured in high school years is the outcome indicator in this study. We used a composite math and reading standardized test score at twelfth grade as the indicator. Test scores were estimates of student academic performance based on IRT modeling, a technique to efficiently generate reliable statistics based on sampled data.[37] "Race-ethnicity" is one of the most conspicuous demographic factors relating to the distribution of equal educational opportunities. Marginalized minority groups, which typically include African Americans, Hispanics, and American Indians, tend to receive education of poorer quality and their academic performances tend to be lower than that of Caucasian students.[38] Minority students are also more likely than their Caucasian peers to attend schools with aged facilities, unqualified

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34. *See* BERKNER & CARROLL, *supra* note 24.
35. NELS: 88/2000 FOURTH FOLLOW-UP, *supra* note 14, at 301.
36. STEVEN J. INGELS ET AL., NAT'L CTR. FOR EDUC. STATISTICS, NATIONAL EDUCATION LONGITUDINAL STUDY OF 1988: SECOND FOLLOW-UP: COMPONENT DATA FILE USER'S MANUAL 2 (1994).
37. *See id*.
38. Asian Americans and Pacific Islanders ("API"), with their unique socio-cultural backgrounds, have relatively high academic performance levels. It is well documented, however, that APIs do experience different difficulties in U.S. public schools, an issue that requires special research. For analytic convenience, this study specifically uses non-Asian minorities in the comparison.

teachers, and constrained financial resources.[39] Race-ethnicity was a five-category variable that included Asian-Pacific Islanders, African Americans, Hispanics, Caucasians, and American Indians. In a multiple regression analysis, the grouping was dichotomous—one for African Americans, Hispanics, and American Indians, and the other for Caucasians and Asian-Pacific Islanders. Combining Caucasians and Asian-Pacific Islanders into a group was based on the established fact that the Asian-Pacific Islander group on average has similar computer access and academic performance as Caucasians.[40] "SES" was indicated by a composite score derived from parents' educational attainment, household income, and household durable consumer goods. Also drawn from the NELS second follow-up data, the scale was standardized with a derived quartile variable. We defined low-income students as those who were in the lowest quartile of the derived SES.

"Computer use" was represented by a series of variables, including student self-reported home computer use, school computer access, frequent use of computers, different modes of computer use, computer coursework, and participation in computer-related enrichment programs. We also examined school-provided information about availability of computers, computer course offerings, graduation requirements for computer courses, and teacher-observed active use of computer labs at school.

To examine the potential generic and differential benefits of technology access in connection to academic achievement, we attempted to sort out complex relationships between a group of relevant explanatory factors and academic performance, including: (1) "School factors" including: school socioeconomic and racial composition; school geographic locale (urban, suburban, and rural); and school provision of computer-related programs and facilities; (2) "Instruction, curricula, and teachers' expectations" indicated by students' placement in advanced placement programs (versus general and vocational programs) and advanced math and science courses; (3) "Teachers' expectations" for students' future education; and (4) "Family resource and support" indicated by SES and parental educational attainment and parents' expectations for their children's educations.

V. ANALYTICAL METHODS

The study will use two sample "t" tests—statistical procedures and multiple regression procedures. In the bivariate analysis, a large number of variables conceptually relevant to academic achievement and computer access were examined. Based on the descriptive and bivariate

39. *See* COMPUTER ACCESS, *supra* note 10; INTERNET ACCESS, *supra* note 10.

40. *See generally* THE BLACK-WHITE TEST SCORE GAP (C. Jencks & M. Phillips, eds., 1998); FALLING THROUGH THE NET, *supra* note 2.

analyses, we then conducted multiple regression analyses to examine the predictor variables' unique and joint relationships with academic performance. A series of initial tests was run to explore alternative equations that could yield a reasonably good fit with the data. We paid particular attention to the testing of two-way interaction effects in order to detect joint effects of predictors on achievement. The tests included interactions between computer use and access and race-ethnicity, SES, schools' computer facilities and programs, curricula, and coursework, teacher expectations, family background, and student educational expectations.

In the final analysis, a series of equations was specified to assess the racial-ethnic and SES gaps in computer access and the possible generic and differential benefits of computers on academic performance. The first equation simply demonstrates the existing racial, ethnic, and SES gaps in computer access. School, program, family, and psycho-behavioral variables subsequently are entered into the equations to estimate how the two gaps might change.

VI. RESULTS

The results are presented in an order corresponding to the research questions and issues posted earlier.

A. Issue 1: The Access Gaps

To address the first research issue, Table C-1 (Appendix C) presents the cross-tabulation. Comparing computer use at home and at school by race-ethnicity, and income, discrepancies emerged. Striking differences occurred across the racial and ethnic groups. Rates among Caucasians and Asian-Pacific Islanders for home computer usage were similar; the differences were not statistically significant. The other groups, however, had significantly lower rates of computer usage than Caucasians. In particular, the rates for Hispanics and American Indians using home computers were much lower than the rate for Caucasians (9.56%, 9.45%, and 25.57%, respectively). African Americans also had lower in-home computer usage rates than Caucasians, but the magnitude of the difference was smaller. Similar racial and ethnic gaps were evident when measured by the frequency of computer usage and the rates of continuous use of computers in both the tenth and twelfth grades. Hispanics and American Indians lagged behind Caucasians in both measures, whereas African Americans and Asian-Pacific Islanders did not differ from Caucasians because the rates were not statistically significantly different. Compared with Caucasians, Hispanics also had a lower average count in science activities in which a computer was used (6.72 and 7.13, $p<0.05$).

Income groups clearly differed in the three measures of computer use and access. Relative to those families with higher incomes, students of lower-income families consistently had lower rates of in-home computer usage and continuous usage of computers during their high school years. Additionally, their computer usage was less frequent than that of the other groups. Both the magnitude and statistical significance of the income-related divide in computer use and access were high. In short, to address the first research issue on access gaps, evidence was found that supported the notion of a "digital divide" relating to race-ethnicity and income. The difference was especially clear with data that indicated actual access to a computer, such as home computer use, frequency of use, and persistence of use. With indicators of access and use at school, the difference was more substantiated between income groups than among racial-ethnic groups. This pattern of gaps in non-school access was broader than gaps in school access and had strong implications, as was evidenced in subsequent multiple regression analyses.

B. Issue 2: The Generic Benefits of Computer Use

We examined the generic benefits of computer use at home and at school with different variables in relation to math and reading composite scores, while controlling for the effects of variables that have been documented as relevant to achievement (*ceteris paribus* for correlation statements thereafter). However, in the multiple regression analysis, there were differences in school CBT access and availability. In Table C-2, the first equation estimated the achievement gaps associated with SES and race-ethnicity. SES is a strong positive predictor of achievement (with beta=5.07, and $p<0.01$). We separately estimated the racial differences with four binary variables, each representing a contrast between a given minority group and Caucasians. The Asian-Pacific Islander group had a higher average score than the Caucasians (with beta=1.26 and $p<0.05$). African Americans, Hispanics, American Indians, and Alaskans had significantly lower average achievement (-2.16, -5.08, -4.85, respectively, all at the $p<0.01$ level). Consistent with prior research, we identified substantial achievement gaps with NELS data.

To identify a generic benefit from computer use and access in raising the achievement level, we entered into the second equation a group of variables measuring computer use and access. Of these variables, only four estimates were statistically significant. Home computer usage in the eighth grade and continuous use of a computer in the tenth and twelfth grades were found to be significantly related to high achievement (with beta values of 0.87 and 0.89, respectively, both at the $p<0.01$ level). Strikingly, computer science courses, as recorded in students' transcripts, were found to relate to low achievement (beta=-1.15 and $p<0.01$). Counts of computer use in science activities were also weakly related to low achievement and marginally statistically significant (beta=-0.10 and $p<0.05$). None of the remaining school measures of computer use (i.e., computer use at school in eighth grade, computer availability at school in eighth grade, teacher-reported computer active use in school, advanced computer program courses provided in the tenth grade, and self-reported computer coursework in the tenth grade) were found to be associated with achievement. While these findings raised more questions than answers, a rough pattern was nevertheless discernible: Computer use in high school did not help improve academic achievement, whereas persistent computer use at home was associated with better achievement.

C. Issue 3: The Differential Benefits

Does computer use help some children but not others? Or does it help one group *more* than other groups? To examine the role of computer use in promoting academic performance of students of different SES and racial-ethnic backgrounds, we separated the analysis by the subgroups. Table C-3 shows multiple regression coefficient estimates for comparison of non-Asian minorities and Asian-Pacific Islanders against Caucasians and comparison of the low SES group (defined by the lowest quartile of the SES composite score) against groups at other SES quartiles. Between the two racial-ethnic groups, there were differences in effects of a number of predictor variables, including locus of control, tenth graders' expectation of receiving a college education, rural schooling, and parental expectations for students' college educations.

Remarkably, a number of computer-relevant variables differed in their relation to achievement across the two groups. Home computer use produced a positive effect on the Asian-Pacific Islander and Caucasian students (beta=0.89 and $p<0.01$), but it did not make a difference among other minority students. Similarly, continuous computer use made no difference among minorities, but had a positive effect on the achievement (beta=1.03 and $p<0.01$) of Caucasian and Asian-Pacific Islander students. One of the surprising findings here is that both self-reported computer course credits and transcripts documenting computer science credits bore a negative correlation to the students' academic achievement across racial-ethnic groups. The low SES group also differed in estimates for computer-related variables from other SES groups. Both home computer usage and continuous computer usage during the high school years were unrelated to the achievement levels of low SES students, but were moderately and positively related to the achievement of other SES groups (with beta values of 1.03 and 0.98, respectively, and both significant at $p<0.01$ level).

D. Issue 4: The Gap-Reduction Effect

How do computer use and access in schools help to narrow achievement gaps associated with income and race-ethnicity? With home computer use at the eighth grade positively related to achievement, we could distinguish the NELS respondents into two groups. A majority group (n=7,494) included the students who did not use computers at home and another group (n=2,218) who did use computers at home. Separately estimating the same regression equation for the two groups revealed considerable differences in academic achievement gaps relating to income, race-ethnicity, and other relevant variables. As can be seen from Table C-4, those students who used computers at home fared much better than those who did not (with beta values of 1.61 versus 0.46) in computer use in both the eighth and tenth grades. What this meant was that those students who used computers at home performed much better in their computer use in school. The gap relating to race differed substantially: Among those who used computers at home, non-Asian minority students performed much worse than their counterparts, all other things being equal. Although the difference in the academic performance between the two groups narrowed among those who did not use computers at home, computer use at home did not narrow the racial-ethnic gap in academic achievement.

On the other hand, using computers at home seemed to produce lower positive results on the students' advanced coursework and the locus of control on achievement. The two estimates were smaller for the group that used computers at home than they were for the group that did not. This finding is interesting in contrast to the increased magnitude of the estimate for non-Asian minority students. It perhaps implies that while accessing computers at home did not help minority children improve their test scores, the access might have helped alleviate the disadvantages imposed by a minority-concentrated school setting.

Educational expectations seemed more predictive of achievement among students who used computers at home than it was among students who did not use computers at home. This included the three variables on expectation by parents, teachers, and the students themselves. The magnitude of the three estimates was consistently larger for the group that used computers at home than in the group that did not. Moreover, the estimate for continuous use of computers in the tenth and twelfth grades also was large and statistically significant for the group that used computers at home (beta=1.61 and p<0.01), but not so in the other groups. This finding suggests that the academic performance of students who had computers at home was positively related to continuous computer use, but this relationship is not clear among students who did not have computers at home.

There are other noteworthy findings in Table C-4. The frequency of using computers in science activities was negatively related to achievement for the group that did not have computers at home (-0.14; significant at p<0.01 level); no such relationship was observed in the group that used computers at home. The negative relationship between computer science credits (in transcripts) and achievement, however, was consistently negative for the two groups.

E. Issue 5: The Technology-School Interaction Effects

We grouped school characteristics into two subsets. One set was for school demographic characteristics, including the geographic locale and school rates of minority students and students who received free or reduced-price lunches. Another set represented school learning environment factors, including two indicators: the provision of advanced computer program courses and the teachers' expectation for a student to go to college. Each of these variables was coded into a dichotomy so that the sample students were in two comparison subgroups on each variable (e.g., students from rural schools versus students from other locales). We then specified a same multiple regression model for each of the subgroups of students and examined the differences in the estimates of the effects of computer use in relation to achievement scores across the comparison subgroups. Such differences, if any, provided some idea regarding the relationship between computer use and academic achievement differentiated by these key school characteristics, while other relevant effects were statistically controlled.

In Table C-5-1, the relationship between using a computer at home and achievement also differed by school minority rates. Among students attending minority-dominated schools (with the rate greater than 40%), the relationship was stronger (beta=1.21 and $p<0.05$) than it was among students attending schools with lower minority rates (beta=-0.79, and $p<0.01$). Furthermore, using a computer in both the tenth and twelfth grades did not relate to achievement for students in schools with high minority rates, but it did fairly strongly for students in other schools (beta=1.25 and $p<0.01$). The pattern seems to indicate that computer use *at home* benefited students going to schools with high minority rates more than it did those students going to schools with low minority rates. However, using a computer continuously during high school years only benefited students who went to schools with low minority rates.

There was a milder difference between the two groups: Student self-reported computer coursework was negatively related to achievement only in the case of students attending schools with low minority rates (beta=-0.17, $p<0.05$) but not in the case of students attending schools with high minority rates. The contrast between the subgroups in high-poverty schools and low-poverty schools revealed virtually the same pattern as reported above. Home computer use related positively to achievement for students in high-poverty schools to a greater extent than for students in low-poverty schools (with beta values of 1.45 and 0.71, respectively, both significant at the $p<0.01$ level). Similarly, continuous computer use in the tenth and twelfth grades related to higher achievement only among students in low-poverty schools, not among those in high-poverty schools.

Achievement was negatively related to computer science courses (recorded in transcripts). This relationship was stronger for students attending low-poverty schools than for students attending high-poverty schools (respectively, beta value of -1.32 and -0.96, both significant at $p<0.01$). This finding is compatible with the relationship between self-reported computer coursework and achievement found in the comparison of students from schools with different minority rates.

Table C-5-2 presents the estimates from four equations for subgroups based on the schools' learning environments. Again, the two indicators of computer use, using a computer at home and continuous computer use throughout the high school years, appeared to differ in relationship to achievement between the subgroups. For students whose teachers expected them to go to college, home computer use was related to higher achievement (beta=1.12 and $p<0.01$); for students whose teachers did not have such expectations, there was no such relationship. On the other hand, the positive relationship between achievement and continuous computer use for students whose teachers did not expect them to go to college seemed stronger than for students whose teachers did expect them to go to college (beta=1.42, p<0.01, and beta=0.82, $p<0.05$, respectively). We found no other substantial differences in computer-school interaction effects.

For students whose schools provided advanced computer program courses, home computer use was not related to achievement; for students whose schools did not provide such courses, home computer use was related to higher achievement (beta=0.95 and $p<0.01$). The relationship between the continuous computer use and achievement among the former group was greater in magnitude than it was among the latter group (beta=1.72 and $p<0.05$ in comparison to beta=0.90 and $p<0.01$, respectively) (see Table C-6-2).

F. Issue 6: The Technology-Individual Interaction Effects

Using the same approaches as in the technology-school interaction analysis, we further examined the relationship between computer use and achievement differentiated by individual attributes. Two student variables were used to separate multiple regression analysis: self-expectation for college education and advanced academic coursework accomplished in high school (see Table C-6, Appendix C).

Among students who expected themselves to go to college, home computer use was strongly and statistically related to greater academic achievement (beta=1.01 and $p<0.01$). Among students who did not expect a college education, the coefficient was small and not statistically significant. The other indicator of computer use, continuing use of a computer in the tenth and twelfth grades, however, did not reveal such a clear pattern.

In the comparison based on students' credits in advanced courses, a number of differences emerged. First, home computer use was related to superior achievement for students who took advanced courses but not for students who did not (beta=1.22 and $p<0.01$ for the former group in contrast with the statistically insignificant estimate for the latter). Again, as expected, students active in academic work are more likely to benefit in achievement from using a computer. Also, the contrast was sharp between the two groups' coefficients associated with continuous use of a computer. Among students who had advanced courses, favorable test scores were related to continued computer use (beta=1.75 and $p<0.01$), but among students who had no advanced coursework, the relationship did not occur (see Table C-6).

VII. DISCUSSION

Our findings support the concept that universal use of computer-based technology does not benefit all public school children by minimizing the achievement gap. On the contrary, due to the inequitable availability of computers at home, the gap may be increasing over time where expectations are differentiated.[41] In effect, computers are not ubiquitous across different social and demographic groups, thereby enforcing a continuation and increase in the achievement gap. Our analysis generated the following findings: (1) when compared with their student peer group, racial-ethnic minorities and children of low socioeconomic status who did not have ready access to home computers lagged behind, but when only school use of computers was compared, there was little difference; (2) for low SES children and minorities, whether computers were used at home or in schools had little effect on performance; (3) generally, while there appears to be statistical variations in computer-related academic results, using computers at school resulted in little increased value to overall achievement—a disappointing conclusion; (4) disadvantaged children generally appear to benefit less than their peers from using computers, be it at home or in school; and (5) statistically, the academic performance of disadvantaged students did not seem to have a correlation to computer use or other independent variables.

The analysis seems to indicate that ill-designed curricula coupled with poor instruction render computer usage irrelevant. Minority and poor children cannot close the achievement gap by use of technology

41. Mary McNabb ET AL., THE SECRETARY'S CONFERENCE ON EDUCATION TECHNOLOGY, CRITICAL ISSUES IN EVALUATING THE EFFECTIVENESS OF INDUSTRY (1999), *at* http://www.ed.gov/Technology/ TechConf/1999/confsum.html.

unsupported by creative instruction designed to stimulate creativity and infuse achievement potential. Social stratification would seem to present insurmountable hurdles in the expectation that technology alone will decrease the achievement gap;[42] indeed technology itself may be a factor in increasing the gap as presently implemented.

VIII. CONCLUSION

Income is a stronger indicator than race regarding the use of computers and students' achievement, and the strength of the evidence seems to be clear that socioeconomic factors appear to play a disturbing role in student access to computers. In many cases, there are demographic correlations between ethnicity and income level. However, affluence is the key factor in determining the positive influence of computer use on student performance. Focus should therefore be given not only to racial minorities but also to the SES minority in order to best implement technology for achievement.

The relationship between home computer use and students' achievement levels increases in cases where advanced coursework is pursued. Home computer use was related to superior achievement for students enrolled in advanced courses but was not a significant factor for students who were not. Similarly, favorable test scores among advanced students were related to continued computer use, but this relationship did not occur among students who did not take advanced courses. The lack of confidence demonstrated by this group derives from their lack of affluence, depriving them of home computers and parental guidance and encouragement. It discourages these students from seeking advanced coursework and compounds the reluctance of school administrators to offer such work to the low-income students. This seems to suggest that advanced coursework, which by its very nature encourages continued computer use, should be made available to all students, regardless of prior performance.

Computer usage offers its most constructive benefits if students are given clear expectations by teachers. The evidence from this study also supports the claim that both the students' motivation and the teachers' expectations are key to students' success in academic performance. Specifically, the students whose teachers expected them to go to college fared much better in using home computers than those students whose teachers did not expect them to go to college. Teachers should make it clear to students how computer technology will benefit them in the future for all types of careers. They should emphasize the computer as an achievement tool and find ways to provide the student with incentives

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42. *See generally* CHARLES R. LAWRENCE III & MARI J. MATSUDA, WE WON'T GO BACK: MAKING THE CASE FOR AFFIRMATIVE ACTION (1997); BARRINGTON MOORE, JR., AUTHORITY AND INEQUALITY UNDER CAPITALISM AND SOCIALISM (1987).

to work independently in order to achieve clearly defined course objectives. It is paramount that the teachers establish standards and high expectations as well as encourage creativity, determination, and the ability to perform research with computer technology. The students should be motivated to incorporate computers into their daily lives as a means of achieving a higher SES. Teachers need to give special attention to teaching strategies involving computers and encourage students to take a more personal interest in computer usage. Thus, computer usage is most constructive if personal motivation of the students is closely associated with teachers' high expectations.

Students participating in computer science courses displayed lower average math and reading test scores, which poses a number of interesting questions; (1) Are students getting lazy because the computer performs so many functions for them?; (2) Does the time devoted to this new class of subjects take away from the time formerly available to pursue the traditional 3Rs?; (3) Have teachers' education abilities deteriorated due to lower entry standards and professional achievement?; or (4) Is computer technology not being integrated into non-computer courses in a successful fashion? While suggestive explanations could be offered, this finding calls for serious research into the processes and techniques of computer science instruction and curricula. Serious consideration needs to be given to teacher technology training, as well as thoughtful integration of technology-centered content into teaching methods. Middle school teacher training must undergo modernization and social attentiveness to the individual needs of students, while teaching educators how to properly integrate technology into every subject they teach. Current methods demonstrably are not working in the sense of making progress in the learning process. Policies and curricula must be developed that speak to the specific issue of improved teaching methods if SES levels are to be raised.

These findings present clear evidence in terms of the relationship between socioeconomic factors, equitable distribution and use of computers, teacher technology training, and students' performance. In light of this, it is imperative that "equity" in school computer usage must involve not only equity in access but also equity in consideration of the learning needs of low-income and minority students. It follows, then, that teacher technology training may be as important as socioeconomic factors in determining the level of SES achievement by the career graduate. Increased access to computers will likely have positive results when the educator has a complete grasp of the role and use of computers as well as an understanding of the students' home environments and how their deficiencies must be corrected in order to realize their full potential, thus enhancing society instead of reducing the average achievement.

IX. APPENDIX A

SAMPLE SIZE AND MISSING CASES ON F2 COGNITIVE TEST BY SEX, RACE/ETHNICITY, AND SES

Table A-1[†]

Sample Sizes and Missing Cases on 2nd Follow-Up (F2) Cognitive Test by Sex, Race/Ethnicity, and SES Quartile: Unweighted NELS Base Year-2nd Follow-Up Panel Data

	Number who completed all 3 tests in BY-F2 panel	*Number with F2 test score available*	*Percent of BY-F2 panel with missing F2 test scores*	*Mean of F2 math test scores*
TOTAL	16,489	12,714	22.9%	51.87
SEX				
Male	8,140	6,284	22.8%	52.13
Female	8,349	6,430	22.9%	51.05
RACE/ETHNICITY[a]				
Asian, Caucasian	12,657	9,935	21.5%	53.16
African American, Hispanic, American Indian	3,823	2,773	27.4%	45.96
SES[b]				
Lowest quartile	3,663	2,635	28.0%	44.90
2nd quartile	3,942	3,063	22.2%	49.04
3rd quartile	4,024	3,149	21.7%	52.11
Highest quartile	4,859	3,867	20.4%	57.73

[†] From U.S. Department of Education, National Center for Education Statistics, National Education Longitudinal Study of 1988, Base Year through Second Follow-Up, 1988-92, the full panel sample.
[a] There are nine cases with missing information on race-ethnicity.
[b] There is one case with missing information on SES.

X. APPENDIX B

DESCRIPTIVE STATISTICS FOR VARIABLES USED IN THE ANALYSIS

Table B-1[†]

Descriptive Statistics for Variables Used in the Analysis (Public School Students Who Did Not Change Schools Between Grades 10 and 12)

Continuous Variable	Label	*N*	Mean	*SD*	Minimum	Maximum
F12XCOMP	Standardized Test Composite (Reading/Math)	9924	50.88	9.63	30.27	71.29
F22XCOMP	F2 Standardized Test Composite (Reading/Math)	9924	50.47	9.73	27.86	71.04
ADVCOURS	Transcripts Advanced HS Courses	9924	4.36	2.83	0.00	15.50
SCHCBT21	F1 Self Reported Computer Course Scale	9804	0.80	1.56	0.00	12.00
SCHCBT22	Computer use in science activities	9804	7.64	3.16	2.00	29.00
MIN_PER	School % Minority	9924	2.83	2.11	0.00	7.00
LUN_PER	School % Free Lunch	9924	3.38	1.91	0.00	7.00
F2RCOM_C	Transcripts Units in Computer Science (NAEP)	9924	0.55	0.70	0.00	9.50
NORMWT	Relative weight	9924	2.07	3.45	0.04	26.10

[†] From U.S. Department of Education, National Center for Education Statistics, National Education Longitudinal Study of 1988, Base Year through Second Follow-Up, 1988-92.

Table B-1 (cont.)

Categorical Variable[43]	Label	*N*	Mean	*SD*	Minimum	Maximum
HMCOMPUT	Home Computer Use Base Year	9924	1.22	0.42	1	2
PCF1F2	Use PC Both F1 & F2	9924	1.18	0.38	1	2
SCHCBT11	By School CBT Active Access	9924	1.33	0.47	1	2
SCHCBT12	By School Computer Availability	9924	1.77	0.42	1	2
SCHCBT13	Teacher Say CBT Active Use	9924	1.03	0.16	1	2
F2RACE2	Asian-Pacific Islander	9924	1.03	0.17	1	5
	African American	9924	1.10	0.30	1	-
	Hispanic	9924	1.13	0.34	1	-
	Caucasian	9924	1.73	0.45	1	-
	Native American	9924	1.01	0.11	1	-
MINORITY	Non-Asian Minority	9924	1.24	0.43	1	2
POOR	Lowest SES quartile	9924	1.25	0.43	1	2
S_EDEXP1	By Student Expect College	9924	1.67	0.47	1	2
S_EDEXP2	F1 Student Expect College	9924	1.59	0.49	1	2
P_EDEXP	By Parent Expect College	9924	1.56	0.50	1	2
TCH_EXPT	Teacher Expect College	9924	1.57	0.50	1	2

[43] Binary variables are coded 1 and 2.

XI. APPENDIX C

Table C-1[†]

Computer Access/Use Gaps: Percentage/Mean of Computer Access/Use by Race-Ethnicity and Low-Income Status Subgroups of Class of 1992

Subgroup	*Home computer use base year %*	*Use computer in both 10th and 12th grades %*	*Average frequency of using computer*[a]	*Computer used in various science activities*[b]
Caucasian	25.57 (0.88)	19.33 (0.69)	1.23 (0.03)	7.13 (0.05)
Asian-Pacific Islander	31.37 (2.91)	23.70 (2.14)	1.40 (0.10)	7.54 (0.19)
Hispanic	9.56 (1.17)*	11.05 (1.60)*	0.97 (0.09)*	6.72 (0.11)*
African American, non-Hispanic	14.04 (1.68)*	13.84 (1.71)	1.21 (0.07)	7.37 (0.22)
American Indian/Native Alaskan	9.49 (4.02)*	7.26 (3.03)*	0.98 (0.18)	7.15 (0.41)
Others	27.66 (0.87)	21.07 (0.68)	1.33 (0.03)	7.25 (0.06)
Low SES students	7.02 (0.56)*	8.02 (0.78)*	0.84 (0.04)**	6.75 (0.11)*

Note: Standard errors appear in parenthesis.

* $p<0.05$ and ** $p<0.01$, with T-test of the null hypothesis that the subgroups do not differ (the contrast is Caucasian in race-ethnicity comparison) in percentage or mean.

† From U.S. Department of Education, National Center for Education Statistics, National Education Longitudinal Study of 1988-1992 (NELS:88/2000), "Base Year" through "Second Follow-Up" panel data.

a A scale with counts of activities where a computer was used; derived from four items in the First Follow-Up data (S29H, F1S29I, F1S29J, and F1S29K).

b Combined two scales ranging from one through five indicating increasing frequency of computer in the tenth and twelfth grades, respectively; see Appendix B for labels.

Table C-2[†]

SES and Racial–Ethnic Gaps in Math and Reading Composite Test Score and Generic Benefit of Access To and Using Computers: Multiple Linear Regression Coefficient Estimates

Predictor Variables	*Equation 1: SES and race–ethnicity gaps*	*Equation 2: Generic benefit of computer access/use*
SES Composite	5.07 (0.17)**	0.85 (0.17)**
RACE–ETHNICITY		
Non-Asian minorities vs. Caucasian	—	-2.91 (0.29)**
Asian-Pacific Islanders vs. Caucasian	1.26 (0.55)*	—
Hispanic vs. Caucasian	-2.16 (0.45)**	—
African American vs. Caucasian	-5.08 (0.44)**	—
American Indian/Alaskan vs. Caucasian	-4.85 (1.27)**	—
Advanced high school courses		1.65 (0.06)**
Locus of control 8th-10th grade		1.36 (0.15)**
School % of minorities		-0.15 (0.07)*
School % of free lunch		-0.15 (0.08)*
Home computer use 8th grade		0.87 (0.20)**
Computer use in both 8th and 10th grades		0.89 (0.26)**
Use computer at school 8th grade		0.05 (0.22)
Computer available at school 8th grade		-0.30 (0.28)
Use computer in science activities		-0.10 (0.04)*
Teacher reported computer actively used in school		0.28 (0.55)
Advanced computer program courses provided-10th grade		0.29 (0.30)
Computer science coursework -transcripts		-1.15 (0.15)**

[†] From U.S. Department of Education, National Center for Education Statistics, National Education Longitudinal Study of 1988 (NELS:88), "Base Year" through "Second Follow-Up" panel data.

Table C-2 (cont.)

Predictor Variables	*Equation 1: SES and race–ethnicity gaps*	*Equation 2: Generic benefit of computer access/use*
Self-reported computer coursework-10th grade		-0.14 (0.07)
Intercept	51.70	47.76
R^2	0.24**	0.54**
Number of parameters	6	20
Number of cases (weighted)	9,924	9,712

Note: Standard errors appear in parenthesis.
* *p*<0.05. ** *p*<0.01.

Table C-3[†]

Examining Differential Benefit of Access To and Using Computer by Race-Ethnicity and SES: Multiple Linear Regression Estimates for Racial-Ethnic and SES Subgroups

Independent Variables	*Non-Asian minorities*	*Asian-Pacific Islanders and Caucasians*	*Low SES group (the lowest SES quartile)*	*Other SES groups*
SES composite	0.97 (0.34)**	0.75 (0.17)**	—	—
Non-Asian minorities	—	—	-3.20 (0.52)**	-3.07 (0.34)**
Advanced high school courses	1.80 (0.13)**	1.61 (0.06)**	1.75 (0.13)**	1.63 (0.06)**
Locus of control 8th and 10th grade	2.29 (0.33)**	1.01 (0.15)**	1.33 (0.30)**	1.38 (0.17)**
School % minorities	-0.21 (0.16)	-0.14 (0.08)	-0.04 (0.13)	-0.18 (0.08)*
School % free lunch	-0.22 (0.16)	-0.13 (0.10)	-0.21 (0.16)	-0.18 (0.09)
Teacher expect student to go to college	1.68 (0.52)**	1.98 (0.26)**	2.02 (0.46)**	1.98 (0.28)**

[†] From U.S. Department of Education, National Center for Education Statistics, National Education Longitudinal Study of 1988 (NELS:88), "Base Year" through "Second Follow-Up" panel data.

Table C-3 (cont.)

Independent Variables	*Non-Asian minorities*	*Asian-Pacific Islanders and Caucasians*	*Low SES group (the lowest SES quartile)*	*Other SES groups*
10th grader expect to go to college	0.99 (0.47)*	1.81 (0.27)**	0.74 (0.45)	2.07 (0.29)**
Parent expect student to go to college	0.12 (0.45)	1.74 (0.27)**	1.22 (0.43)**	1.50 (0.28)**
Home computer use 8th grade	0.60 (0.59)	0.89 (0.21)**	0.83 (0.65)	1.03 (0.21)**
Computer use in both 10th and 12th grade	0.07 (0.63)	1.03 (0.28)**	0.64 (0.88)	0.98 (0.27)**
Use computer in science activities	-0.17(0.05)**	-0.07 (0.05)	-0.13 (0.07)*	-0.09 (0.05)
Computer science coursework-transcript	-1.33(0.31)**	-1.12 (0.17)**	-0.88 (0.43)*	-1.34 (0.17)**
Self-reported computer coursework 10th grade	0.02 (0.14)	-0.18 (0.08)*	-0.20 (0.14)	-0.10 (0.09)
Intercept	44.85	51.29 (0.97)**	44.33	48.78
R^2	0.47**	0.51**	0.39**	0.52**
Number of parameters	19	19	19	19
Number of cases (weighted)	2,324	7,384	2,377	7,334

Note: Standard errors appear in parentheses.
* p<0.05. ** p<0.01.

Table C-4[†]

Gap-Reduction Effect: Multiple Linear Regression Coefficient Estimates in Equations for Students Who Used PC at Home and Students Who Did Not

Predictor Variables	*Group that did not use PC at home*	*Group that used PC at home*
SES composite	0.86 (0.20)**	0.90 (0.27)**
Non-Asian minorities vs. Caucasians	-2.66 (0.34)**	-3.75 (0.59)**
Advanced high school courses	1.72 (0.07)**	1.44 (0.07)**
Locus of control 8th-10th grade	1.37 (0.17)**	1.23 (0.26)**
School % of minorities	-0.20 (0.08)*	0.03 (0.11)
School % of free lunch	-0.18 (0.09)	-0.09 (0.11)
Rural school	0.50 (0.27)	0.07 (0.36)
Teacher expect student to go to college	1.76 (0.27)**	2.51 (0.45)**
10th grader expect to go to college	1.47 (0.27)**	2.10 (0.50)**
Parents expect student to go to college	1.23 (0.27)**	1.64 (0.47)**
Computer use in both 8th and 10th grades	0.46 (0.34)	1.61 (0.35)**
Use computer at school-8th grade	0.17 (0.25)	-0.34 (0.34)
Computer available at school–8th grade	-0.36 (0.31)	-0.09 (0.41)
Use computer in science activities	-0.14 (0.04)**	-0.02 (0.07)
Teacher reported computer active use in school	0.27 (060)	0.50 (0.75)
Advanced computer program courses provided-10th grade	0.35 (0.33)	0.16 (0.42)
Computer science coursework-provided-10th grade	-1.07 (0.19)**	-1.48 (0.23)**

[†] From U.S. Department of Education, National Center for Education Statistics, National Education Longitudinal Study of 1988 (NELS:88), "Base Year" through "Second Follow-Up" panel data.

Self-reported computer coursework-10th grade	-0.12 (0.09)	-0.13 (0.10)
Predictor variables	*Group that did not use PC at home*	*Group that used PC at home*
Intercept	46.77	47.49
R^2	0.51**	0.52**
Number of parameters	19	19
Number of cases (weighted)	7,494	2,218

Note: Standard errors appear in parentheses.
* p<0.05. ** p<0.01.

Table C-5-1[†]
Technology-School Interaction: Multiple Linear Regression Estimates in Equations Separated by Subgroups Who Attend Schools of Different Demographics

Predictor Variables	*Students of school with minority > 40%*	*Students of school with minority ≤ 40%*	*Students of high-poverty schools*[a]	*Students of low-poverty schools*
Non-Asian minorities	-2.97 (0.49)**	-2.89 (0.34)**	-3.04 (0.45)**	-2.75 (0.37)
SES Composite	0.76 (0.34)*	0.83 (0.17)**	0.90 (0.28)**	0.79 (0.19)**
Advanced high school courses	1.72 (0.12)**	1.60 (0.06)**	1.68 (0.12)**	1.62 (0.06)**
Locus of control 8th & 10th grade	1.56 (0.32)**	1.25 (0.16)**	1.55 (0.25)**	1.20 (0.17)**
School % minority	—	—	-0.14 (0.10)	-0.12 (0.09)
School % free lunch	-0.30 (0.15)	-0.12 (0.10)	—	—
Rural school	-0.37 (0.45)	0.66 (0.28)*	-0.14 (0.40)	0.71 (0.30)*
10th grader expect to go to college	1.14 (0.51)*	1.84 (0.26)**	1.87 (0.42)**	1.50 (0.29)**

[†] From U.S. Department of Education, National Center for Education Statistics, National Education Longitudinal Study of 1988 (NELS:88), "Base Year" through "Second Follow-Up" panel data.
[a] Poverty schools are defined by the rate of students who received free or reduced price lunches; schools with a rate higher than 30% are defined as high-poverty, otherwise as low-poverty. Data were weighted by the relative panel weight (the By-F2 panel weight F2PNLWT divided by its mean).

Table C-5-1 (cont.)

Predictor Variables	*Students of school with minority > 40%*	*Students of school with minority ≤ 40%*	*Students of high-poverty schools*	*Students of low-poverty schools*
Parent expect student to go to college	0.52 (0.46)	1.56 (0.27)**	0.27 (0.37)	1.82 (0.30)**
Teacher expect student to go to college	1.61 (0.54)**	2.00 (0.26)**	1.92 (0.42)**	1.92 (0.29)**
Home computer use 8th grade	1.21 (0.57)*	0.79 (0.21)**	1.45 (0.41)**	0.71 (0.22)**
Computer use in both 10th and 12th grade	0.01 (0.54)	1.25 (0.28)**	0.09 (0.43)	1.32 (0.30)**
Use computer at school 8th grade	0.19 (0.45)	-0.01 (0.24)	0.35 (0.36)	-0.07 (0.26)
Computer available at school 8th grade	0.11 (0.56)	-0.48 (0.31)	0.31 (0.46)	-0.40 (0.34)
Computer use in science activities	-0.23 (0.05)**	-0.16 (0.04)**	-0.23 (0.04)**	-0.15 (0.05)**
Computer science coursework – transcripts	-0.90 (0.31)**	-1.26 (0.17)**	-0.96 (0.25)**	-1.32 (0.18)**
Self-reported computer coursework 10th grade	0.06 (0.14)	-0.17 (0.08)*	-0.03 (0.12)	-0.17 (0.08)
Intercept	47.44	48.60	46.46	48.83
R^2	0.50**	0.53**	0.52**	0.53**
Number of Parameters	19	19	19	19
N of weighted cases	2,329	7,383	3,113	6,599

Note: Standard errors appear in parentheses.
* $p<0.05$. ** $p<0.01$.

Table C-5-2†

Technology-School Interaction: Multiple Linear Regression Estimates in Equations Separated by Subgroups Who Attend Schools of Different Learning Environments

Predictor Variables	*Students whose teacher expects them to go to college*	*Students whose teacher did not expect them to go to college*	*Students whose school provides advanced computer courses*	*Students whose school provides no advanced computer courses*
Non-Asian Minorities	-3.07 (0.37)**	-2.62 (0.48)**	-3.58 (0.64)**	-2.68 (0.33)**
SES Composite	0.89 (0.20)**	0.81 (0.27)**	0.73 (0.38)	0.87 (0.18)**
Advanced high school courses	1.58 (0.06)**	1.77 (0.11)**	1.56 (0.09)**	1.66 (0.07)**
Locus of control 8th & 10th Grade	1.24 (0.19)**	1.42 (0.23)**	1.19 (0.37)**	1.36 (0.16)**
School % minority	-0.12 (0.09)	-0.21 (0.11)	0.02 (0.16)	-0.18 (0.08)*
School % free lunch	-0.17 (0.11)	-0.11 (0.12)	-0.15 (0.14)	-0.15 (0.10)
Rural school	0.42 (0.28)	0.41 (0.37)	-0.14 (0.49)	0.47 (0.27)
10th grader expect to go to college	1.71 (0.32)**	1.45 (0.39)**	1.91 (0.57)**	1.56 (0.27)**
Parent expect student to go to college	1.05 (0.34)**	1.49 (0.34)**	1.17 (0.61)	1.28 (0.26)**
Teacher expect student to go to college	—	—	2.21 (0.70)**	1.86 (0.26)**

† From U.S. Department of Education, National Center for Education Statistics, National Education Longitudinal Study of 1988 (NELS:88), "Base Year" through "Second Follow-Up" panel data. Data were weighted by the relative panel weight (the By-F2 panel weight F2PNLWT divided by its mean).

Table C-5-2 (cont.)

Predictor Variables	*Students whose teacher expects them to go to college*	*Students whose teacher did not expect them to go to college*	*Students whose school provides advanced computer courses*	*Students whose school provides no advanced computer courses*
Home computer use 8th grade	1.12 (0.24)**	0.43 (0.39)	0.74 (0.46)	0.95 (0.22)**
Computer use in both 10th and 12th grade	0.82 (0.30)*	1.42 (0.50)**	1.72 (0.69)*	0.90 (0.26)**
Use computer at school 8th grade	0.19 (0.26)	-0.13 (0.35)	-0.25 (0.45)	0.04 (0.24)
Computer available at school 8th grade	-0.34 (0.34)	-0.31 (0.41)	1.00 (0.75)	-0.25 (0.30)
Computer use in science activities	-0.15 (0.06)*	-0.21 (0.04)**	-0.23 (0.08)**	-0.18 (0.04)**
Teacher reported computer active use in school	0.63 (0.59)	-0.17 (0.94)	1.74 (1.32)	-0.02 (0.56)
Advanced computer program courses provided 10th grade	0.31 (0.37)	0.26 (0.49)	—	—
Computer science coursework–transcripts	-1.12 (0.18)**	-1.35 (0.27)**	-1.63 (0.38)**	-1.11 (0.16)**
Intercept	48.79	46.22	50.15	47.99
R^2	0.44**	0.39**	0.57**	0.54**
Number of parameters	19	19	19	19
Number of weighted cases	5,653	4,059	1,375	8,336

Note: Standard errors appear in parentheses.

* $p<0.05$. ** $p<0.01$.

Table C-6†

Technology-Individual Interaction: Multiple Linear Regression Interaction Effects Estimates in Equations Separated by Subgroups With Different Educational Expectations

Predictor Variables	*Students who expect to go to college*	*Students who did not expect to go to college*	*Students who took advanced courses*	*Students who took no advanced courses*
Non-Asian minorities	-3.08 (0.35)**	-2.62 (0.48)**	-3.32 (0.31)**	-0.44 (1.54)
SES composite	0.93 (0.19)**	0.72 (0.27)*	1.38 (0.18)**	1.92 (0.72)*
Advanced high school courses	1.60 (0.06)**	1.69 (0.11)**	—	—
Locus of control 8th & 10th grade	1.42 (0.18)**	1.21 (0.23)**	1.93(0.16)**	1.50 (0.60)*
School % minority	-0.18 (0.09)*	-0.13 (0.11)	-0.14 (0.07)*	-0.14 (0.31)
School % free lunch	-0.16 (0.10)	-0.11 (0.12)	-0.18 (0.08)*	-0.17 (0.21)
Rural school	0.36 (0.28)	0.47 (0.37)	0.01 (0.26)	-0.25 (0.99)
10th grader expect to go to college	—	—	3.80 (0.24)**	1.45 (1.36)
Parent expect student to go to college	1.11 (0.32)**	1.49 (0.33)**	2.40 (0.25)**	1.29 (1.50)
Teacher expect student to go to college	1.87 (0.31)**	1.88 (0.37)**	4.09 (0.26)**	1.57 (1.63)
Home computer use 8th grade	1.01 (0.23)**	0.56 (0.41)	1.22 (0.22)**	-0.74 (1.27)
Computer use in both 10th and 12th grade	0.81 (0.27)**	1.40 (0.53)*	1.75 (0.26)**	-1.77 (1.03)

† From U.S. Department of Education, National Center for Education Statistics, National Education Longitudinal Study of 1988 (NELS:88), "Base Year" through "Second Follow-Up" panel data.

Table C-6 (cont.)

Predictor Variables	*Students who expect to go to college*	*Students who did not expect to go to college*	*Students who took advanced courses*	*Students who took no advanced courses*
Use computer at school 8th grade	0.29 (0.25)	0.60 (0.33)	0.12(0.24)	-1.15 (0.92)
Computer available at school 8th grade	-0.44 (0.34)	-0.15 (0.36)	-0.15 (0.30)	2.22 (1.07)*
Computer use in science activities	-0.10 (0.05)*	-0.28 (0.04)**	-0.22 (0.03)**	-0.24 (0.08)**
Teacher reported computer active use in school	1.05 (0.63)	-1.12 (0.89)	0.10 (0.62)	-0.62 (1.89)
Advanced computer program courses provided 10th grade	0.32 (0.31)	0.28 (0.50)	1.31 (0.32)**	-0.80 (1.86)
Computer science coursework – transcripts	-1.41 (0.17)**	-0.85 (0.26)**	0.69 (0.19)**	N.A.[a]
Self-reported computer coursework 10th grade	-0.07 (0.09)	-0.20 (0.12)	-0.10 (0.07)	-0.47 (0.29)
Intercept	48.48	46.59	58.56	45.58
R^2	0.48**	0.35**	0.42**	0.20**
Number of parameters	19	19	19	19
N of weighted cases	4,836	3,875	9,365	346

Note: Standard errors appear in parentheses.
* $p<0.05$. ** $p<0.01$.

[a] This subgroup did not have any credits in computer science coursework, as the group definition implies.