TECHNOLOGY AND QUALITY OF EDUCATION FOR LOW-INCOME AND MINORITY STUDENTS: ISSUES AND POLICY IMPLICATION

BY

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O-517

ABSTRACT

The purpose of this study was to examine 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 socio-economic groups. A database constructed from the 1988-1992 National Education Longitudinal Study (NELS) was utilized in order to investigate the relationships between the availability of technology to secondary-level students, SES factors, and academic achievement overall.

Descriptive statistics of the groups were used alongside multiple regressions in order to analyze group differences as well as the interactions of differing variables and their impact on students' achievement. The findings suggest that, with other relevant conditions constant: (a) disadvantaged students did not lag far behind their peers in computer use at school, but they were much less likely to use computers at home; (b) computer use at home was far more significant than computer use at school in relation to high academic performance; (c) using a computer at school seemed to have dubious effects on learning--taking computer science courses at school related consistently to low performance for both the disadvantaged and their peers; (d) disadvantaged students benefited less than other students from computer use, including computer use at home; and (e) compared to their peers, disadvantaged students' academic performance seemed less predictable by computer use and other predictor variables. The findings of this study present clear evidence linking SES factors, availability of computer technology, and student performance. In short, when discussing "equity" in terms of educational use of computers, it is important not only to consider access, but also the individual learning needs of students.

ACKNOWLEDGEMENTS

As I wrote the last word of my dissertation, the hour hand of the quartz clock on the wall happened to reach six o'clock. Another exciting night had passed, a threadlike light of dawning rising on the horizon. With my back gently leaning on the chair. I enjoyed the comfort that the ray of light has brought to my soul.

Such is human life, linked by numberless days and nights with diligence and pleasure, tension and relaxation, and struggle and enjoyment intermixed. It is like a splendid and undulating movement composed of pitch and secondary pitch, and the tango and waltz, with one climax following another, singing the praises of all the values of human life. Accompanying the melodious movement, every piece of moving music has branded the education that a person has received, and it is the very sincere sacrifice of a soul she/he received due to her/his education.

I would like to express my sincere gratitude to the following individuals who assisted me in bringing this piece of work to fruition:

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daughter, Heng, in Canada; and my parents, in China, have been my primary sources of support and motivation, to whom this piece of work is dedicated.

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CHAPTER 1

INTRODUCTION

Assuming that technology injected directly into our existing educational system will uniformly benefit all children is overly simplistic and inaccurate. In this study it was reasoned that technology can only improve academic performance if it is delivered hand-in-hand with a learning-oriented school environment along with changes in the traditional teaching model, which encourage learning and intellectual activity in children. Computers and their availability alone cannot narrow the gap between different socioeconomic groups; their placement must be accompanied by an effort to increase the availability of educational opportunities and the uniformly high expectations of students.

This study accomplished three tasks through: (a) a literature review to form a conceptual framework and a set of research questions to study educational technology in relation to equal educational opportunity, (b) an analysis of data from the National Education Longitudinal Study of 1988 to1992 to address the specified research questions, and (c) reported the findings and drew policy implications from the study.

Background of the Study

The ideal that all citizens have the right to equal educational opportunities regardless of race, color, religion, or national origin claimed its legal status as a result of the *Brown v. Board of Education* decision in 1954 and the 1964 Civil Rights Act (Lawrence & Matsuda 1997). Equality of educational opportunity (EEO), according to Coleman (1990), one of the most influential education researchers of our time, means "providing a common curriculum for all children, regardless of their backgrounds" (p. 20). This concept holds that society fulfills its responsibility of providing equal educational opportunity only if the same schooling and the same curriculum are available free of charge to all children up to a certain level. With such limited standards, equal opportunity can be quantitatively measured in terms of educational resources distributed across schools (Dorfman, 1978, p. 24). The application of the concept, "equality of educational opportunity," requires value judgments of words, equality, and opportunity. Endorsement of the concept alone does not adequately explain why the point is a concept, such as referenced in Lieberman (1961), Komisar (1964), Green (1971).

Another view of equal educational opportunity goes beyond a quantitative match of resources. In this perspective, as an intrinsic requirement of fairness, equal education should be more than just providing the same schooling and curriculum; instead, it must pursue the goal that every individual realizes his or her most and best potential through education (Tumin, 1965). Because children are from different backgrounds with different needs, schools are responsible for providing *differential* programs to help them achieve the highest possible level and to compensate for their background variations (Johns, Alexander, & Rossmiller, 1969). In other words, equal opportunity entails not merely equal treatment but also additional accommodations of individuals' educational needs, because equity and justice cannot be assured through equal treatment of unequals (Alexander, 1982).

The two legal perspectives regarding equal opportunity are corresponding to the distinction between an input-oriented definition and a process- and result-oriented definition of EEO in educational research. The classic conception of EEO defines the equality largely in terms of educational *input*, including money, facilities, staffing, and other resources (e.g., Coleman, 1990). Later development of theories goes further to look into the equality of educational output and, especially, the learning process under a rubric of quality of education (Hurn, 1993). This expansion of the classic concept is still controversial as critics question the feasibility and even the necessity of such result-oriented EEO in a free market society, pointing out inequalities in the larger society that are far broader than what the educational institution can possibly control (Boudon, 1974; Hurn, 1993). Nevertheless, the idea seems to have gained increasing recognition among educators and education policymakers. It may be inevitable to broaden the ideal of equitable opportunity, given the vast and profound societal changes that have been underway in recent years. The growing diversity of the U.S. population poses challenges to the status quo of public education (e.g., NCES. 1999a). The rising political power of minorities demands redistributing resources for schooling of the disadvantaged (Lawrence & Matsude. 1997). The decades' shifting ideologies and social consensus increasingly values education as a fundamental mechanism for social justice and social mobility (e.g., Verstegen & Whitney. 1997). Finally. the long-term economic prosperity in the U.S. not only affords more resources for children and public education in general. but also makes it possible to seek large-scaled remedy for past inequality so as to narrow the difference in educational results (Moore. 1987).

With either the classic or the expanded definition. educational opportunity is nevertheless not equally distributed in reality. The most conspicuous demographic factors relating to the distribution of the opportunity are race-ethnicity and socioeconomic status (SES). Minority groups. typically including African-Americans. Hispanics. and Native-American Indians. tend to receive education of poor quality and to perform low academically relative to Whites.[1] Minority students are more likely than their White peers to attend schools with aged facilities. unqualified teachers. and constrained financial support (NCES. 1999). They are more likely to be placed in inferior academic programs and to receive unchallenging instruction with a low expectation (e.g.. Coleman. 1990: Oakes. 1990). National statistics show that minority children at different age levels consistently lack behind their White peers in major academic subject (Jencks & Phillips. 1998: NCES. 1998).

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[1] Asian Americans and Pacific Islanders (API). with their unique sociocultural backgrounds. achieve relatively high in academic performance. It is well documented. however, that APIs do experience in the U.S. public school systems different difficulties, an issue that requires special research. For analytic convenience, this study specifically uses non-Asian minorities in the comparison due the limited scope of work.

SES, a construct that covers occupational status, educational attainment, and income, is a widely accepted determinant of quality of education (e.g., Halsey, Lauder, Brown, & Wells, 1997). Compared with the others, children with family backgrounds of unskilled labor, poor education, and low income are more likely to perform poorly in schools, to receive deficient instruction, and to achieve low academically (NCES, 1999). In multivariate analyses that simultaneously take into consideration different factors influential to academic learning, SES is often found to be the single most powerful predictor of achievement (e.g., Halsey et al., 1997).

Policy makers and educators have explored a variety of approaches to reduce the gaps in educational input and output associated with race-ethnicity and SES. Such efforts involve improving equity in resource allocation, rigorous requirements for teacher education and certification, standardization of curriculum and instruction, and school reforms that emphasize local decision making and accountability. These efforts have achieved limited success in some areas, but the results are far from being satisfactory. It is striking to observe that, in some cases, even when the input side (e.g., spending, facilities, and teacher quality) approached equitable level, children of minority and poor backgrounds still do not perform as well as White students (e.g., McMahon & Geske, 1982). Input-based EEO is obviously not sufficient as either a conceptual tool or a policymaking goal for the public education system to move forward toward equity.

Conceptualizing the Role of Technology

The dramatic advance of technologies applicable to education has raised high hopes among those who are concerned about EEO issues. Technologies seem to be a promising means to help educators realize the ideal of EEO, as many believe that with powerful yet cost-effective technologies, minority and poor children should be able to receive education of the same quality as their more fortunate peers (Gladieux & Swail, 1999). New computing and networking technologies have the potential to enable disadvantaged students to access knowledge-building and communication tools and thus to provide them with more individualized learning opportunities (Gladieux & Swail, 1999; National Science Foundation, 1996).

The skeptics question whether technologies are really going to drastically improve educational equity. For one thing, access to technologies is not even across sociodemographic categories since it is largely determined by resources available to the schools, communities, and households (Gladieux & Swail, 1999; U.S. Department of Commerce, 1999). In addition, the way of using technologies may be affected by the characteristics of groups and individuals. As advantage magnifies advantage, some warn that rapid changing technologies applied in education may even widen the existing gaps in educational quality across the racial and socioeconomic categories (Gladieux & Swail, 1999; Hoffman & Novak, 1998; Warschauer, 2000).

Clearly, gaps exist in access to technologies by households of different sociodemographic groups. As national statistics reveal, the rates of computer ownership, access to the Internet, and using computer and the Web-based technology in home and at work are significantly lower among households of minority, low-income, and low educational attainment (U.S. Department of Commerce, 1999). Research indicated that schools' access to technologies is largely constrained by the available financial resources. Although federal and state policies provide funding to alleviate the unequal distribution of school resources and to encourage technology application, gaps in resources for technological application remain substantial across socioeconomic levels and localities (U.S. Department of Commerce, 1999). Given the limited resources, schools with large portions of minority and low-income students are unable to provide adequate equipment and programs for students to access technologies. Recent national school survey data show that the progress in computer and the Internet access is uneven, with significantly lower rates for schools with large numbers of students of minority and low SES backgrounds (NCES, 1999b). 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 engage in advanced computer application at school, such as analysis of complex systems and college-oriented academic work. In contrast, students who have no experience with a computer at home often are placed in computer courses emphasizing routine skill learning or work place-oriented training (e.g., Warschaurer, 2000; Wenglinsky, 1998).

Further, the ways in which educational technologies are used in instruction and learning may vary by schools and by individual students (National Science Foundation, 1996). For example, Michaels, Cazden, and Bruce (1985) found that poor schools tend to use computers mainly for student drilling work, whereas affluent schools use technology-supported programs to help students learn research and creative skills. While middle class students, especially those who are in advanced programs (e.g., gifted and Talented Education) receive instruction which encourages learner initiative (programming and problem solving). Low income and ethnic minority students receive instruction which maintains the control of learning within the program (computer-aided drill and practice (Michaels, Cazden, & Bruce, 1985). Such qualitative distinction of learning using similar technologies may represent another form of inequality and probably will not reduce the gap in the quality of education associated with SES and race-ethnicity (National Science Foundation, 1997).

Individual psychological and behavioral patterns are another potentially confounding factor related to the effect of technological application on quality of education. A recent study (Warschauer, 2000) suggests that computer-based educational programs did not benefit female students as much as it benefited male students because females were likely to be disinterested in the learning settings presented by the available computer products, typically with drastic movement and even violent images. Girls tend to use a computer for interpersonal and social purposes; whereas boys tend to use a computer to gain power and control of the physical environment (Viadero, 1994). Relative to White and Asian-American children, Black and Hispanic children were less motivated to participate in computer-based programs because of a misperception of computers and mathematics as overwhelmingly complicated (National Science Foundation, 1997). It is conceivable that children who are motivated toward intellectual growth can learn tremendously through computer- and network-based learning. As such, technologies present them with vast amounts of information in an interactive fashion. By contrast, children who lack intellectual interest could spend a great deal of time on a computer and the Internet yet end up with an addiction to electronic games, pornography, and other self-indulgent activities. In short, access to technologies per se potentially may either reduce or widen gaps between the advantaged and the disadvantaged, depending on how policies and programs are developed (National Science Foundation, 1996).

Research is needed 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. Specifically, empirical studies should focus on how the provision of and the access to computer-related technologies interact with school environment, family setting, and children's psycho-behavioral attributes to enhance academic learning among minority and low-income children. By ascertaining such interaction effects, research can help educators and policy makers to develop appropriate programs and policies to better serve disadvantaged children's needs with technologies. This study examined such issues based on an analysis of a national longitudinal data set available from the National Center for Education Statistics (NCES).

Statement of the Problem

With the notion of outcome-focused quality of education, academic performance is a salient indicator of the concept in analysis of the influence of educational technology. Particularly, a standardized cognitive test administered to a nationally representative sample of high school students offers measures of outcome-oriented EEO that is comparable across geographic and sociodemographic categories. Because educational outcomes are influenced by many factors, in a sound comparison of outcomes in relation to the focal predictors in this study (access to technologies, race, and SES), other critically important influences on the outcomes were considered simultaneously. Such factors included instruction/curriculum programs, school environment, teachers' expectation, parent support, and children's motivation and learning behavior, just to name a few. Statistically controlling for such key predictors of academic achievement, this analysis focused on the relationship between access to technology and academic performance with other major conditions being equal. Specifically, the study attempted to address the following research questions and issues (all statements are made *ceteris paribus*):

1. How does high school students' access to computer-based technologies (CBT) vary by race-ethnicity and SES (Issue 1: the access gaps)?

2. How does CBT access at school and home relate to high school students' academic achievement (Issue 2: the generic benefits)?

3. Does the relationship between CBT access and academic achievement differ across racial-ethnic and SES subgroups (Issue 3: the differential benefits)?

4. Without access to computer at home, does CBT access *at school* relate to higher academic performance of minority and low-SES students (Issue 4: the gap-reduction effect)?

5. How do CBT access and school experiences (instruction/curriculum programs, school environment, teachers' expectations) jointly relate to academic performance and reduce or widen the gaps associated with race-ethnicity and SES (Issue 5: the technology-school interaction effects)?

6. How do CBT access and individual psycho-behavioral attributes (motivation to learn, educational and occupational aspiration, and learning behavior) jointly relate to academic performance and reduce or widen the gaps associated with race-ethnicity and SES (Issue 6: the technology-individual interaction effects)?

Purpose of the Study

The study focused on a two-fold goal: First, it was intended to inform the education community and policymakers regarding the effect of CBT access on the quality of education in terms of academic performance. Examining the cognitive gains by students who had access to CBT in contrast with students who did not during the high school years, the analysis attempted to isolate and assess the relationship between CBT and the educational outcome. More importantly, by scrutinizing the differential effect of CBT on cognitive growth by minority/low-income students in comparison with White students, the analysis examined whether the CBT actually helped reduce the achievement gap related to race-ethnicity and SES. The results could help answer policy questions as to whether and the extent to which the investment in computer technologies improves student learning in general and educational equity in particular.

Second, the study may provide insights for computer-based instruction and curriculum development. This will be accomplished by exploring specific school conditions and individual students' psychobehavioral attributes in connection to computer use and academic performance during the high school years. The results should help identify patterns in which CBT works effectively in conjunction with school context and individual characteristics for enhancing learning growth. Knowledge of such patterns can facilitate new designs and improvement of computer-based instruction and curriculum.

Significance of the Study

Prior research and evaluation studies of educational technologies applied to elementary and secondary education have accumulated a sizable literature. A large portion of such research, however, has focused on whether or not the applied technology made a difference in student learning *in general*. Relatively few studies have paid systematic attention to the issue of differential effects of technologies on student subgroups, particularly minority and low-income students vis-à-vis White and middle-class students.

Largely composed of specific program evaluations, the smaller literature that links technologies to educational equity as a central concern is insufficient on two accounts: First, most of such studies were pre and posttest comparisons of the outcomes in a given school/program or among disadvantaged students themselves, rather than intent comparison of disadvantaged and the "mainstream" students. Second, such program evaluations did not offer a broad picture of technology access in connection to improvement of equity simply because they were locally conducted (for a sample list of such studies, see National Science Foundation, 1997). Thus, technologies' potential differential effect on the "haves and the have-nots," or the "advantage-magnifies-advantage" effect (Gladieux & Swail, 1999), remain unclear. Technologies' hopeful impact in reducing, rather than maintaining or even widening the educational opportunity gap, is still elusive.

This study was to remedy such weakness of the existing research. Specifically, the study focused on equity in access to technologies and in the consequential educational outcome, namely, student cognitive growth. As stated earlier, the analysis paid particular attention to the differential effect of CBT access on academic performance by disadvantage subgroups, including minority and low-income students, and by White middle-class students.

Moreover, the study yielded information on technology and educational equity beyond the local or regional boundaries. Drawing on the national longitudinal survey data, the analysis described the patterns of technological application and related student learning in a broad context. Supplementary to the available evaluation studies, such a national portrayal of the relationships between technological access and academic progress across different student categories should contribute to a fuller understanding of the influence of the rapid changing technologies on the struggle for equal opportunity in public education.

CHAPTER 2

REVIEW OF THE LITERATURE

Introduction

It seems overly simplistic to assume that technologies applied to education will uniformly benefit all children in terms of quality of education they receive. In the present study, it was reasoned that technologies may improve the outcome-focused measure of educational opportunity only if access to technologies is conditioned by a learning-oriented school environment and children's motivation to intellectual learning. Furthermore, to reduce the existing gaps in quality of education associated with race-ethnicity and SES, it would not suffice simply to make technologies available at schools. While the uneven availability of technologies must be addressed, equalizing educational opportunity should entail offering access to technologies in an organized school setting where academic learning is valued, expectation to all children is high, and children are motivated to learn. To sort out the theoretical complexity in these relationships, a brief historic reflection of the concepts and a review of the pertinent empirical research are in order.

Defining Educational Opportunity

The concept of educational opportunity arose with the emerging public education in America. The concept could be traced back to the 19th century when the industrial revolution took place and developed rapidly in Europe and America (Coleman, 1990). It has experienced various changes since it came into existence in America. At the beginning, educational opportunity was differentiated according to one's racial identity. Minority groups were excluded from equal participation in the society until after the Civil Rights Movement in the 1950s and 1960s. For example, African-Americans were forced to be slaves in the early history of the U.S. Because of the Civil War, African-Americans were finally incorporated as its free citizens of America. However, in spite of these formally declared rights, African-Americans were not actually enjoying the same substantive rights as Whites for decades.

The Civil Rights Movement, in some sense, set a direct ideology base for the result-oriented concept of EEO. During the 60s and 70s, the result-oriented concept of equality of educational opportunity evolved in the whole educational system. The struggle for racial equality played a fundamental part in the evolution of the concept from input-oriented to outcome-oriented criterion (Coleman, 1990). It was not until the second half of the 20th century when the notion of equality of educational opportunity began to be applied to minority groups who played an important role in the evolution of this concept. While some would say that size of family, early upbringing, etc., should be considered as contributing factors for opportunity, endorsers of the concept need not feel guilty about ignoring these factors in favor of investigating existing social and economic environments with a view towards customizing the education to fit the needs of the children. Value judgments are a necessary evil to most fairly distribute educational opportunity, but such judgments can be supported when research has been accomplished to examine the discrete variables which affect the ability and resource of a student to assimilate the most appropriate education for his/her objectives (Ennis, 1976).

Racial discrimination is still a problem in our society, and "inequality is growing at a rapid rate and the nation's children are the primary victims" (Anderson, 1993, p. 4). The real problem was "the failure of American leaders to use American power to create equal opportunity in life as well as law" for all its citizens (Lawrence & Matsude, 1997, p. 15). It is generally agreed that the equality concept should be implemented for student populations; however, the actual definition of equality and opportunity may vary according to the dictates of local administrations, social organizations parents, and even the students themselves. It may that subjective situational decisions will have to be made relative to socioeconomic environments in order for real equity to be achieved (Ennis, 1976).

Legislation and Policymaking

The most radical legal remedy of social injustice and inequality is the Affirmative Action program, which derived from the evolution of the concept of educational opportunity. Assessing whether a program or policy is effective must begin with a clear understanding of the desired goal or outcome. Some argue that the ultimate goal of any Affirmative Action program is to promote the core American value of equal opportunity (Ennis, 1976). Affirmative Action is also associated with two terms: equality of opportunity and equality of result. Equality of opportunity is referred to "the right to compete, attain, based on merit and not be impeded by race, gender, religion, national origin or sexual orientation" (Orfield, 1993, p. 10). They argued that the right to have equal opportunity is often accepted without argument. They also indicated that the right for equality of results is much more challenging and controversial. To simply remove discriminatory barriers is not sufficient. Furthermore, groups who have been oppressed historically cannot start at the same point that other groups who have no experience of oppression.

Preferential policies in the U.S. are institutionalized. Affirmative Action as a legal provision makes its implementation hard to challenge. The practice of this provision has become a concrete representation of equality guaranteed by the Constitution. Although controversies abound, the revocation of this provision has to be voted on at the state level instead of being adjudicated by the federal government. This procedure is educational in and by itself (Hoffman, 1993).

Any policy for reducing inequality of opportunity would have no significant effects when it is only pointed to educational variables rather than social and economic factors. The author argues that while judicial action was necessary to end racial segregation and discrimination and to uphold the American principles of justice and equality, only community support and grassroots political pressure can produce equitable, quality public school systems (Hoffman, 1993). Although

Affirmation Action has been in effect for decades, the inequality of educational opportunities still exist. This might be attributed to the fact that education has been mainly in the control of the local governments. Anderson (1993) pointed out that the system of local political control and educational policy made it possible that the well-to-do children who live in more affluent districts get a higher quality of education than children of the poor because schools in poor communities get less funding, less educational resources, and less concern from those in control of the educational system. To implement the theory of equality of educational opportunity, we can only herein say that a series of related investigations must be made to resolve the distinctions between a legislative solution vis-a vis a scientific solution. The legislative body needs to develop discrete criteria based on comparative socioeconomic environments to truly evaluate what is equal and what is opportunity relative to the populations involved (Ennis, 1976). Policy making at the federal level has a two-fold purpose: first of all, to make policies to equalize opportunities; second, but also more important, to provide incentives for local governments and institutions to implement them to solve local problems.

Economic Conditions

Another important contextual factor conducive to the evolution of the concept of EEO is the U.S. economic prosperity. When the concept of result-oriented EEO was introduced, the cruel and primitive capital accumulation in America has finished, and Americans were experiencing affluence in their lives. The economic success not only enabled America to improve input of all schools so that schools are better equipped than they were used to, it also made possible to redistribute some necessary resources to seek a large-scaled remedy for the past inequality so as to, in some degree, achieve equality in result.

Ideally, advanced economic development and growth provide conditions and resources for the government to invest more in those schools with limited resources. However, the reality is that some groups (African-American students) "experienced the highest rate of school-poverty in both rural and urban areas" (Anderson, 1997, p. 23). It is also true that the gap is increasing between schools in high-SES neighborhoods and those in low-SES ones, although the economy is prospering. America could have realized the equality in educational opportunity in the sense of input with its highly developed economy. The wide gaps existing in the incomes of the citizens and communities may worsen the equal educational opportunity if the government does not mediate and balance the situation. In general, the investment in schools from the government will, to a certain degree, change the situations for the better, but cannot eradicate the inequality of educational opportunities without challenging and reforming other social factors. Since today's technology plays a significant role in the development of economy, the government, when making policies, needs to be aware of the importance of the role that technology plays in reducing the gaps or increasing the gaps in the quality of education afforded to students.

Technology: Closing or Widening the Gap

Recent development of information technology has heightened interest among educators who are concerned about equity and excellence. With a great potential to enhance learning in generic terms, technology nevertheless may either reduce or widen the educational opportunity gap between the advantaged and the disadvantaged, depending on the policy and implementation of technologies (Gladieux & Swail, 1999; Panel on Educational Technology, 1997). It remains a concern that disparities exist in the access to and use of information technology by students of different backgrounds, including SES, race-ethnicity, gender, geographical location, and special needs (National Science Foundation, 1996).

A most attractive feature of the new computer and communication technology is its ability to engage students in individualized learning. Such applications, typically based on interactive computer-based systems, offer instruction and learning materials that can be controlled by the user in terms of content selection, pace of progress, and options of instruction/learning styles. Ranging from drill-and-practice to sophisticated inquiry and analytical studies, such systems accommodate learners' unique needs, intellectual orientations, and backgrounds. This may, among other functions, reduce the need for teachers to present material with a hypothetical "typical" student and thereby leave some students behind while the others are bored in a conventional setting. With such applications, theoretically, remedial, advanced, or otherwise, personalized instruction that is most needed for disadvantaged children may be delivered at affordable costs. New technologies thus promise to offer an equal education opportunity--beyond the same school and same curriculum--to all children.

Technology makes it possible for people to access vast information and conduct inquiries in a far more efficient way than ever before. The so-called "virtual technology" promises to deliver instruction at a reduced cost. For example, it is possible to package the best teachers' courses for dissemination on the Internet to a world-wide student body (Gladieux & Swail, 1999). Such widespread sharing of the best instruction and curriculum apparently is a powerful way ever available in the history.

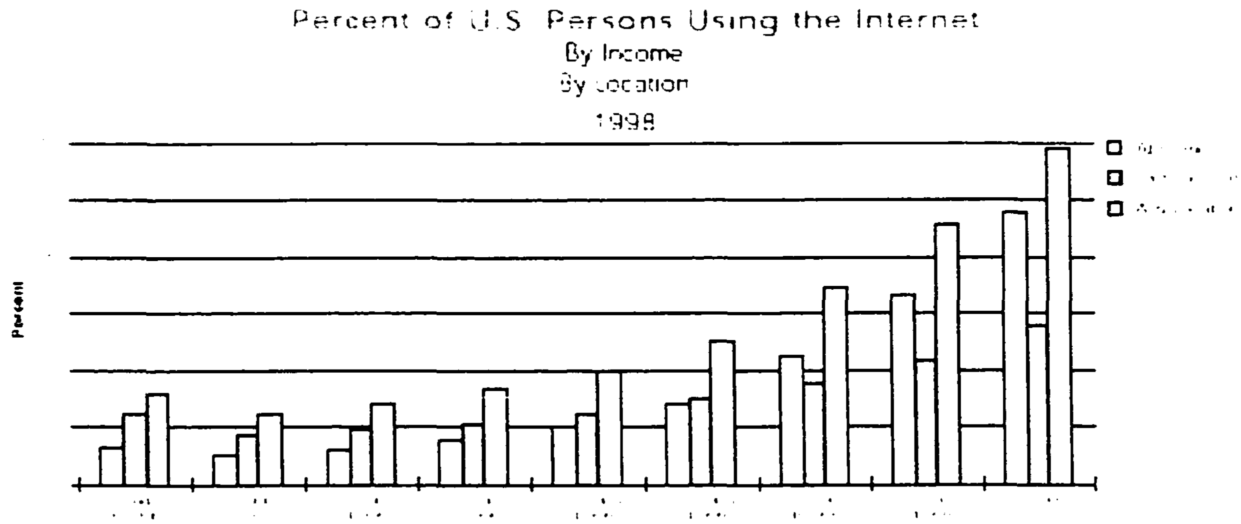
On the other hand, cutting-edge technology incurs high costs to start up. It also requires frequent upgrading and regular maintenance. In addition, teachers and staff need continuous training to keep abreast to the technological changes (Gladieux & Swail, 1999; Green, 1997; National Science Foundation, 1996). It is unclear so far as to whether online instruction could generate savings for students, because some institutions and programs are actually charging higher fees than they did before with conventional delivery approaches (Baer, 1998). The cost to the end user leads to the concern regarding the new technology's impact in closing opportunity gaps associated with race and SES.

Perhaps more significant to the equity concern is the uncertainty regarding whether the advanced educational technology really benefits all students. "There is a persistent and substantial inequality in the access to new technologies among both schools and school children" (Michaels et al., 1985, p. 36). There is little information available to determine whether online instruction has reached the most needy populations; perhaps, it simply accommodates those who already take advantage of many available educational opportunities (Barley, 1997). Some pinpoint the danger that technologies may even widen the educational opportunity gap with a phrase "advantage magnifies advantage." It refers to the possibility that the most advantaged individuals and schools are more able to benefit from cutting-edge technologies; whereas the most needy groups benefit least (Gladieux & Swail, 1999).

A most recent national survey provides some evidence to support the skepticism. Access to new technology has not been equal across social and demographic groups. Based on a household survey, the U.S. Department of Commerce (1999) reports clear patterns of uneven distribution of access to technologies, including computer and Web-TV ownership, Internet access, and email use.

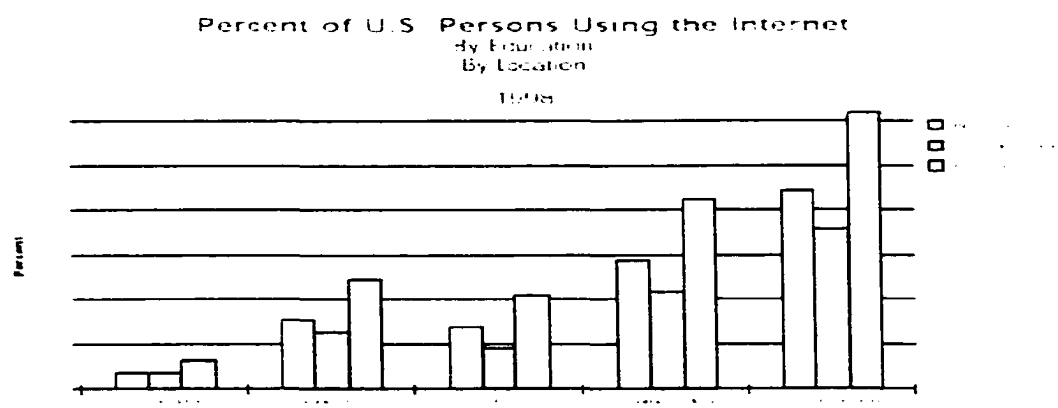
In Figure 1, statistics reveal that income is a clearly a determinant of access to the Internet. The rates of Internet access among individuals in the highest income category ($75,000) are much higher than the rates among those in the low-income categories (below $14,000). Worse, the gaps are wide in both access rates at home and outside home, implying that community and school access does not make up the unequal access for the low-income groups.

Figure 2 shows the Internet access difference across education levels. People with college education are three timely more likely than those who did not finish high school to access the Internet either at home or outside home. Figure 3 demonstrates that race-ethnicity is another important stratification factor in the Internet access. Black and Hispanic are much less likely to have the access at home compared with Whites and Asian Pacific Islanders, although the outside home access indicates that the gap is narrower.



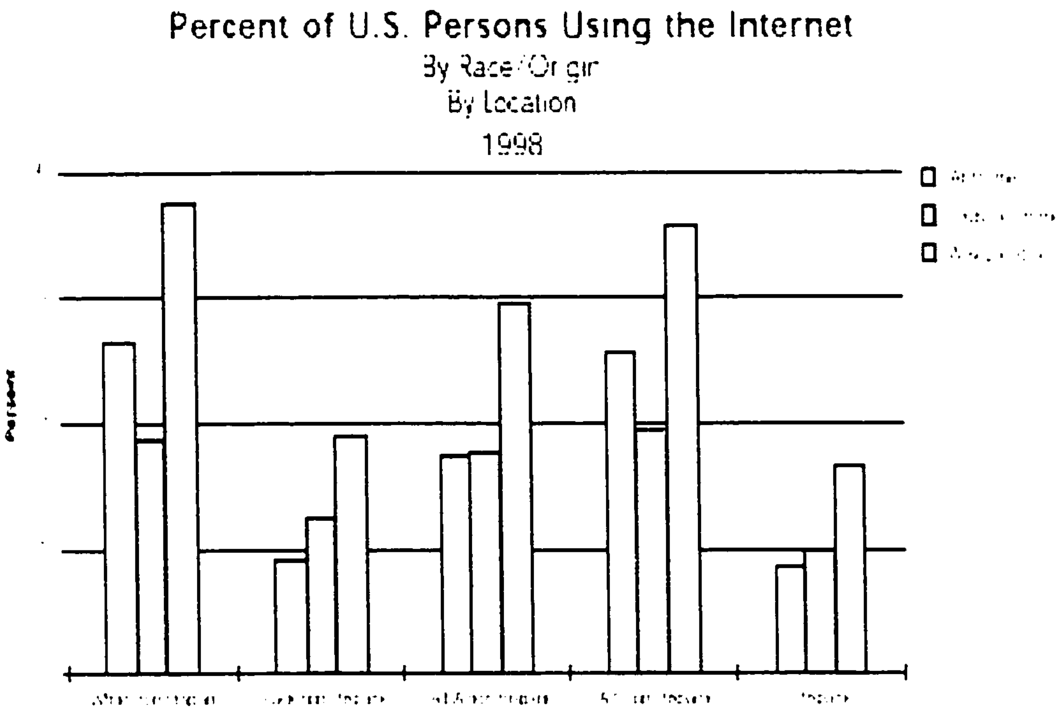
	At Home	Outside Home	Any Location
Under $5,000	6.5	12.[illegible]	16.0
5,000-9,999	5.1	8.7	12.1
10,000-14,999	6.0	9.5	13.9
15,000-19,999	7.7	10.5	16.6
20,000-24,999	9.9	12.[illegible]	19.9
25,000-34,999	14.1	14.9	25.3
35,000-49,999	22.5	17.[illegible]	34.7
50,000-74,999	33.1	21.[illegible]	45.5
75,000+	47.7	28.0	58.9

Figure 1. Percent of U.S. persons using the Internet by income and by education.



	At Home	Outside Home	Any Location
Elementary	3.8	3.8	6.6
Some H.S.	[illegible]	[illegible]	[illegible]
H.S. Diploma/GED	13.8	[illegible]	20.9
Some college	28.7	21.[illegible]	42.[illegible]
B.A. or more	44.5	35.0	51.6

Figure 2. Percent of U.S. persons using the Internet by education and by location.



	At Home	Outside Home	Any Location
White non Hispanic	26.7	18.8	37.7
Black non Hispanic	9.2	12.4	19.0
AIEA non Hispanic	17.5	17.8	29.5
API non Hispanic	25.6	14.4	35.9
Hispanic	8.7	10.0	16.6

Figure 3. Percent of U.S. persons using the Internet by race/origin and by location.

Remarkably, the access gaps have been widening in recent years. The differences between White and Hispanic households, and between White and Black households, are now approximately five percentage points larger than they were in 1997. The digital divides based on education and income level have also increased in the last year alone. Between 1997 and 1998, the divide between those at the highest and lowest education levels increased 25%, and the divide between those at the highest and lowest income levels grew 29% (U.S. Department of Commerce, 1999).

School and other public institutions, while expected to help remedy the unequal distribution of technological benefit, seem to have limited success. The U.S. Department of Education report (NCES, 1999b) suggests that uneven availability and access remain across public schools with different socioeconomic student populations. This survey measured access with percent of schools with Internet access, percent of instructional rooms with Internet access in schools, and ratio of students per instructional computer with Internet access. On all these measures, schools with large proportion of poor students (receiving free or reduced price lunch) rated low relative to schools with small portion of poor students. The good news is that there is substantial improvement in equity access during years 1994 to 1999, as revealed by the narrowed gap in most of these measures.

To examine the process that teachers lead students using computer and the Internet, there are differences cross SES categories of students. In percentage of teachers reporting using computers or the Internet for instruction and the percentage assigning various uses to students, the U.S. Department of Education's recent survey (NCES, 2000a) found substantial differences between affluent and poor schools (respectively, defined as having less than 10% and more than 70% of students eligible for free or reduced-price school lunch). Teachers and students in poor schools were more likely to use computer for drill practice and less likely to use it for research work (respectively, 35% and 18%), compared with their counterparts in affluent schools (26% and 39%, respectively).

Disadvantaged students are more likely to attend unchallenging computer-related courses and they are more likely to be taught in computer literacy classes than to use computers in the course of learning in key subject areas. Moreover, when high-SES students are exposed to computers as a subject area, they 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 drill-and-practice or other skill-building or knowledge acquisition activities) than low-SES students of the same grade levels. With such higher-order computer activities, high-SES students disproportionately receive better opportunities for learning relative to poor and minority students. The disparities, in the mode of computer use, represent a form of inequity at least as important as the disparities in computer availability and accessibility.

With national statistics as a backdrop, some in-depth qualitative studies of technology-based school reform are highly informative. One such study (Warschauer, 2000) made contrast between an elite private school and an impoverished public school. The reforms introduced at the two schools appeared similar, but underlying differences in resources and expectations served to reinforce patterns by which the two schools channel students into an academic, college-oriented future vis-à-vis vocation-geared workplaces. The study concluded that increased use of technology in the schools is bound to heighten distinctions among students based on class and race, as well as other demarcates (Warschauer, 2000). It lends support for both the optimistic and skeptic perspectives regarding technology-based reform and inequality. Schools of diverse socioeconomic circumstances can carry out the types of technology-enhanced reform that make education more interactive--and productive. But these reforms that take place in a social context of stratification will likely make education *more* unequal (Warschauer, 2000).

The researcher found that the public high school's reform process, including the use of technology, is geared toward better preparing students for the workforce. Teachers work to help students develop the types of technological literacy and human relations skills that might be needed in the workplace, without great emphasis on academic content. The majority of students in the communications program take either radio production or video production. Most students focus principally on learning technical skills, such as how to videotape or how to edit a radio program. Likewise, a minority of students who take Web production concentrate their effort on the technical aspects of Web page production.

In contrast, at the elite private school, students worked on Web page development as a part-time paid job, rather than as part of their academic course load. The expectations, policies, and teaching and learning conditions differ dramatically between the two schools. The school is designed to produce the academic and professional leaders of tomorrow. Discussions of school reform are framed by the goal of helping students meet the requirements and expectations of the most prestigious universities. For example, in the biology classes, students use computers to perform the same types of analysis and research that a university researcher might perform, rather than to produce a newsletter (Windschitl & Sahl, 2002).

As a hopeful means to reduce inequality in educational opportunity, the distribution of technology itself is socially stratified. In light of the rapid developments in technology and related educational programs, assessing the impact of technology calls for systematic research that links changing technology to the notion of outcome-oriented EEO. Educational outcomes are products of multiple social institutions including federal and state government, local schools, the community, and the family, in addition to individual efforts. Because of the revolution in information technology, technology has become a key issue in the debate of equitable education. In the following section, discussion focuses on factors that may interact with technology in influencing the quality of education for low-income minority students.

Summary

Equality of education opportunity (EEO) is an idea that continues to evolve as a result of shifting social, political, and ideological forces of yesterday and today. The evolution from input-oriented to outcome-oriented EEO in both theorization and empirical research highlights the ideal of public education struggling to ensure equal chance for success for all children by offering individualized remedial services for those who are disadvantaged by race, sex, socioeconomic status, language backgrounds, and so forth.

Technology has great potential to improve the quality of education and to materialize EEO for all students. It promises to enable students of different backgrounds to learn on an individualized basis. This promise, not yet realized as observed so far, is immediately relevant to the notion of outcome-oriented equal education to the extent the implementation and practical utility of technology recognizes and attempts to accommodate the diverse needs among the disadvantaged.

However, the social forces influencing the distribution of educational opportunity also influence the distribution of technology. "Advantage magnifies advantage" is a pattern evident in technological application. Those who are privileged to have computer and Internet access at home, for instance, are far more likely than the rest to use technology for high level thinking and complex research activities. Thus, the way technology is deployed and used with the students has greater impact on the quality of education to all students. The purpose of this study was to advance the knowledge about the utility of technology in closing the educational opportunity gap. With the literature review and specified research questions, this study examined the interplay of technology and various social factors relevant to learning, including school context and resource, curriculum programs and teacher expectation, family support, and individual attributes.

CHAPTER 3

THEORETICAL FRAMEWORKS

Conceptual Framework

The impact of the technological changes on the education of the students in general and for specific groups of students is hard to measure because of the many confounding issues involved. Neither theoretical work nor empirical research in the literature is sufficient for understanding the potentially profound yet complicate impact of technologies on the equity of educational opportunity. With largely program evaluation studies, little systematic theorizing is available for understanding the actual role of new technologies in improving educational equity. To remedy such a dearth of knowledge, a conceptual framework is needed to underpin empirical investigation.

Generic and Differential Benefits

It is conceivable to see the technological impact on equitable educational opportunity with two constructs, *technically generic benefits* and *socially differentiated benefits*. The notion technically generic benefits refer to the idealized application of information technology that is expected to consistently benefit every student. Socially differential benefits, in contrast, point to the practical effects of technology that vary by social settings of its application and social grouping of its users. The dual notion of benefits is the central concern that motivates this study.

Under the rubric of technically generic benefit, educational applications of technology such as online instruction and interactive-based systems allow learners to readily access vast information and to individualize the learning process to accommodate the learner's unique needs, abilities, interests, and the learning styles (Gladieux & Swail, 1999). Gaining momentum from a "constructivist" perspective, technology is also used to support changes in the pedagogic models, including changes from whole-class to small-group instruction, from teacher-centered to student-centered, and from all students learning the same things to different students learning different things (Liu, 1998). Many hope that new computing and networking technologies would empower historically disadvantaged groups with greater access to the different knowledge-building and communication tools that might help them to over-come some of their disadvantages. Such arguments for generic benefits are partly supported by some of the available studies (Lee& Bryk. 1988).

The perspective of technological inequality is driven by the concern of socially differential benefits. This framework draws on research demonstrating that low-income and minority students do not equally benefit from the advanced technology as their more fortunate peers do (see. for example, Wenglinsky. 1998). Disadvantaged children either have less access to new technologies or are more likely to use them for rote learning activities rather than for intellectually demanding inquiries.

The social conditions in which educational technologies are actually implemented and used determine whether they serve to narrow the historical disparities or widen them even further (Cubberley. 1996). In analyzing integration of technology into instruction, research has found that the traditional patterns of classroom organization might be impermeable to change. even with the introduction of large numbers of computers into schools (Coons. Clune & Sugarman. 1997: Warschauer. 2000). Such research suggests that even in situations where the computers are widely used in instruction does not necessarily result in systematic improvement of learning opportunities. Computers. Internet use. emails. Web-TVs, and interactive instruction may not touch the fundamental social stratification in the education establishment that is all too familiar to people. As discussed earlier. technology may even reinforce patterns by which schools channels students into distinctive social strata and fulfill education's traditional role of social reproduction (Coleman 1990).

Outcome-Oriented EEO

As presented in earlier sections, the idea of equal educational opportunity has been enriched by increasingly focusing on the educational processes and outcomes, in addition to the input. One of the most salient indicators of outcome-oriented EEO is academic performance or cognitive growth in longitudinal measurement. Student academic performance, twice measured in high school years, was the focal outcome indicator in the present study. This outcome variable's positive relationship with technology access was seen as indication of generic benefit; whereas its varying relationship with technology access altered by race-ethnicity and SES was seen as an indication of differential benefits.

Race-Ethnicity and SES

Race-ethnicity was examined with a five-categorical variable including the five major groups in census: Asian Pacific Islanders (API), Black, Hispanic, White, and Native American Indians. Alternatively, the grouping may be in dichotomous, one for Black, Hispanic, and American Indian; and the other for White and API. Combining White and API into a group is based on the established fact that the API group on average has similar CBT access and academic performance as whites (see, for example, Jencks & Phillips, 1998; U.S. Department of Commerce, 1999; NCES 1999b). Such different grouping was also for the convenience of analysis and interpretation.

SES is a concept that involves measures of educational attainment, occupational status, and income and wealth. This study will use composite variables in either continuous or quartile scales to indicate the concept.

Computer-Based Technology Access

As the focus predictor variable, the concept was represented by a series of variables, including home computer ownership and access, school computer access, frequent use of computer, different modes of computer use, computer coursework (literacy, application, and programming), and participation in computer-related enrichment programs.

Interactive Factors

To examine the potential generic and differential benefits of technology access in connection to outcome-oriented EEO, this study sorted out complex relationships between relevant explanatory factors and academic performance. Among many things influential to educational quality, school resource, instruction/curriculum, teacher expectation, family resource and support, and individual students' motivation to learning, are probably the most active factors that interact with technology and jointly determine the academic performance. To understand how technology works, it was necessary to examine it together with the above factors in explaining the educational outcomes.

School Resources

School resource commonly refers to the financial and material support available for operating the school, including indicators such as revenue and capital outlay, spending per pupil, teacher-to-student ratio, educational equipment and facilities, and availability of CBT. Distribution of resources across schools, to a large extent, determines educational opportunities afforded to individual students. The recent federal legislative initiatives support education reform and application of technology. The Improving America's School Act of 1994 authorized $200 million for technology education in 1995 and an addition $200 million for the new education infrastructure improvement grants. Goals 2000: The Educate America Act (passed in 1994) establishes an Office of Educational Technology in the U.S. Department Education. Central to both these Acts is the idea that children are entitled to an opportunity to acquire the knowledge and skills contained in these standards often referred to as an opportunity to learn (National Science Board, 1998).

Coleman (1990) described the nature of school facilities, services, and curricula accessible to various racial groups. He pointed out that a minority elementary student was less likely to attend a school with sufficient textbooks. "Only 84 percent of the Negro elementary pupils attend schools having enough texts, compared to 94 percent of the white pupils in the same counties" (p. 76).

Minority secondary students are less likely to attend schools offering college preparatory curricula than white students (Coleman, 1990).

Availability of computer related technology is closely related to school resource. Although the gap related to access to the computer is closing in public schools, schools with the highest concentration of poor children have the least (and most obsolete) equipment (Catsambis, 1994). The lack of resources in schools has serious implications on the quality of education they receive.

Curriculum and Instruction

Curriculum and instruction in secondary school major subject areas are crucial conditions interacting with technology to affect educational opportunity and student achievement. College-bound, academic programs tend to use CBT for advanced learning and complex research work. Schools that provide advanced math and science courses offer students opportunities for in-depth learning in these subjects and consequently high performance (Oakes, 1990; Peng, Wright, & Hill, 1995). In advanced programs, intense curriculum and high expectations compel students of different backgrounds to learn. In contrast, inferior curriculum and poor instruction often disadvantage female and minority students to a greater extent than they do to other students (Catsambis, 1994; Ware & Lee, 1988). It is so, perhaps, because disadvantaged children are more dependent on school for cognitive growth and lack supplementary learning at home, which is often available to other students. As a result of the poor instruction and curriculum, many disadvantaged students are ill prepared for using computer technology to engage in meaningful learning.

Learning opportunities indicated by curriculum provision in some high schools is often organized by ability grouping or tacking. Commonly, students are grouped in three curriculum tracks: academic or college preparation, vocational and technology, and the general programs (Oakes, 1990). Such tracking systems in math and science have been criticized as much to the disadvantage of minority and low-income students because more often than not, they have lesser chance to be in academic programs (Oakes, 1990; Ware & Lee, 1988). Some researchers say that schools that provide curriculum via ability grouping tend to compromise equity of student learning (e.g., Coleman & Hoffer, 1987; Lee & Bryk, 1988).

Equitable access depends not only on the number of computers available within a given school but on the extent to which those computers (along with other educational technologies) are actually used by various groups and the modes of usage associated with each group. At schools, certain groups participate in creative applications or other "higher-order" learning and problem-solving activities, while others use tech-nology primarily for routine drill-and-practice exercises. School programs and curricula largely determine *how* technology is used in instruction. In inferior curriculum programs, African-American students and Hispanic students are more likely to use computers for drill and practice, whereas White and Asian students are more likely to use them for simulations or applications; the same differences appear between poor students and wealthier students (Wenglinsky, 1998).

Having learned less cognitively and suffered in motivation and confidence, students in low-ability track are less likely to take advantage of high technology for productive learning, even if technology is available. As described earlier, school programs, visions, and expectation for students powerfully regulate the function of technology to generate distinctive outcomes (Warschauer, 2000).

Teachers' Influence

Teachers' professional training, experience, and commitment are undoubtedly among the most important factors determining students' learning and growth. The quality of teachers has been a great concern over the years (National Science Foundation, 1999). According to the Fast Response Survey System conducted by the National Center for Education Statistics (NCES) in 1998, less than half of American teachers report feeling "very well prepared" to meet many challenges. For example, about 20% of the teachers felt prepared for integrating technology into classroom instruction, teaching limited English proficient or culturally diverse students, and students with disabilities (20%), and using student performance assessment techniques (28%). These figures show that many teachers are not prepared to address the challenging needs of the students, in particular students who have the most needs such as low-income minority students. And many of the teachers get burned out because of frustration or inability to work with these students. Lewis, Pasmat, Carey, Bartfai, Farris, and Smerdon (as cited in NECS, 1999b) reported that 12% of general elementary classroom teachers with three or fewer years of experience had emergency or temporary certification. In inner city public schools where the majority of the students are from low-income and from minority families, the number may be much higher. Differences in teachers training in technology-based instruction are a precondition for using technology ef-fectively in their teaching. There is evi-dence suggesting that significant differences in the technology-related preparation of and ongoing support available to teachers in schools exist across socioeco-nomic lines (National Science Foundation, 1999). Wealthy school districts may be able to recruit teachers with greater expertise in the use of educational technologies by offering above-average salaries, or to offer their existing teachers more technology-related training and technical support. Poorer schools, on the other hand, may have fewer teachers capable of making effective use of educational technologies, thus limiting both the quality and quantity of computer use by their students. Recently release national data also reveal that the sophistication of computer use among teachers varies by school wealth (NCES, 2000a).

Teachers' expectation of their students influences student learning and performance. Studies have found a relationship between teacher expectation and student performance. In those studies, teacher expectations, positive or negative, closely parallel subsequent student performance (Windschitl & Sahl, 2002).

A teacher's expectation often refers to the level of academic success the teacher expects for the student to achieve (Hamburg, 1984). There was a close relationship between the students' motivation and teacher expectations. Also important to motivation was a personalized learning environment. She also found that teachers had lower teacher expectations for minority students. Low student motivation could attribute to disengagement from school, feelings of helplessness, and the lack of a clear vision of the future for Hispanic students.

Berkner, Chavez, and Carroll (1997) indicated that teachers do not expect Mexican-American children or minority children as a group to excel in school. School districts appeared to lack a commitment to the Mexican-American student, thereby allowing institutional racism and racial bias to flourish. She suggested that in order to develop insight and awareness to counteract the negative expectations of teachers, it is recommended that boards of education, community groups, district administrators, and government agencies make a commitment to develop and implement programs that are sensitive to the needs of Mexican-American children. And teachers need to be trained and made more aware of the vast influence that their attitudes and prejudices have on pupils.

The quality of math and science teachers was found as an important predictor of students' learning. For instance, teachers may interact with minority and low-income students in ways different from that they interact with the others, characterized by low demanding, passive feedback, and attributing failure to students' lack of ability (Catsambis, 1994). It was argued that the shrinking pool of minorities who are willing to teach science and math at elementary and secondary levels makes it difficult for minority students to find their role model (Seymour & Hewitt, 1997).

Family Factors

It is common sense that the family plays a crucial role in children's education and academic achievement. Family resource--including both material resource and social capital (Ennis, 1976)--and home environment often function to cultivate intellectual growth and foster the fundamental value and social norm for the child. Relevant to the use of technology, family resource is obviously an important determinant of availability of computer-related technology.

The richer the family, the more likely it is to own and use computers. White families are three times as likely as Blacks or Hispanics to have computers in the home (U.S. Department of Commerce, 1999). Wealthy families are much more likely than poor families to own a home computer; and White families are more likely than Black families to own one. Black and Hispanic families trail White families in computer ownership by a substantial margin even within the same income groups (NCES, 1998). It is critically important to have home computer access in order to effectively use computer to learn in school. Research has found that children with access to computer and the Internet at home are more confident and resourceful in using computer-related technology at school (Gladieux & Swail. 1999). Lack of access at home, even when access is provided at school, many poor and minority children may be handicapped in both skills and psychology in productively using computer and other technologies. Home access to computer and the Internet differentiated by SES may be one of the most significant sources of educational inequity in thc United States (Gladieux & Swail, 1999).

Hypotheses

It seems uncertain to specify formal hypotheses for empirical testing in this study, for the loose conceptual ground and limited information available in the literature do not warrant explicit hypothesizing. To maintain the research logarithm, however, the following suggestive statements are proposed to guide the analysis.

CBT access may have limited generic effect on academic achievement. It may interact with race and SES in that it relates to academic achievement among White/API and high-SES students to an extent greater than among minority students. Computer use at home, hypothetically, interact with an access computer at school in relation to academic performance (i.e., having access both at home and school may relate to high performance to an extent greater than an additive effect of the two variables); whereas without home computer use, the relationship between school access and academic performance may not be substantial.

It is also hypothesized that CBT access' relationship with academic achievement is conditioned by school resource, curriculum/instruction, and teacher expectation. In other words, only under conditions of resourceful, academically-geared school setting, strong academic programs, and high expectation by teachers, does students' achievement positively relate to CBT access. Furthermore, CBT access interact with students psychobehavioral characteristics in that it positively relates to academic achievement only among students who are intellectually motivated and who take advanced courses.

CHAPTER 4

METHODOLOGY AND DATA SOURCE

Ideally, data from an experimental design can best answer the questions about the impact of technology on educational outcomes. Unfortunately, to the author's knowledge, few data on the issue are available based on experimental designs in a scope wider than, say, state. With some locally conducted experimental studies, most were limited within schools or school districts in scope (see National Science Foundation, 1999). In light of vastly diverse local circumstances and distinctive definition of technology and education outcomes, such studies could hardly generate cogent statements regarding the complicated consequences of educational technology in public education.

To address the proposed research questions, at minimal, it requires large-scale information with comparable measures of computer-based technology (CBT) access and academic performance. It also requires a research design that allows correlation analysis based on some sort of chronic sequence of events such that predictors of or antecedents to outcome-focused educational quality can be reasonably well identified and assessed. Additionally, to statistically control for the confounding effects and to scrutinize joint effects, such data sources should include considerably broad information about school and family relevant to computer use and academic achievement.

The National Education Longitudinal Study of 1988-92 (NELS) offers such a data source. This dataset meets the basic requirements for analyzing relationship between CBT access and academic performance and allows statistical control and estimation that projects to the student population in the U.S.

NELS Data

NELS is a general-purpose national survey for studying secondary education in the 1990s, with extensive information about secondary school student background and school experience (Berkner, Chavez, & Carroll, 1997). NELS began its base year data collection in 1988 when the sampled cohort was in 8th grade. Follow-up surveys were conducted in 1990, 1992, and 1994, and the last wave of data collection is underway in 2000 (NCES, 2000b). The resulting large data set allows a wide range of research utility, including cross-sectional, longitudinal, and cross-cohort (comparing with cohorts in earlier national longitudinal surveys) analyses.

Specifically, NELS offers a number of strengths for studying CBT access-related issues. First, it incorporates *multiple information sources* (students, parents, teachers, and school administrators), high school transcripts, and academic test results. It is possible to systematically examine the technology access at home and school as portrayed by different informants and link the access measures to the educational outcomes, namely, cognitive growth. Second, NELS provides an enormous amount of *school-level data*, including data on school climate collected from students and administrators and on school provision of equipment and programs related to CBT access. Third, the survey *followed up the cohort* through out their secondary school years and beyond, collecting three-wave standard measures of students' academic performance--as well as vast information about respondents' social behavior and school experience. These individual-level data, by design, are linked to school data for multilevel analysis. This data source offers a rare opportunity for in-depth analysis of CBT access and educational outcomes in terms of academic performance or cognitive growth during the last decade of the 20th century.

Survey Methods

Research conducted by the National Opinion Research Center (NORC), NESL: 88, began in 1988 (base year) to survey approximately 25,000 8th graders from 1,025 schools in a nationally representative sample design. The base-year students were selected using a two-stage stratified probability design, with schools as the first-stage units and students within schools as the second-stage units. From a national frame of about 39,000 schools with 8th graders, a pool of 1,032 schools was selected through stratified sampling with probability of selection proportional to their estimated 8th-grade enrollment. A pool of 1,032 replacement schools was selected by the same method to be used as substitutions for ineligible or refusal schools in the initial pool. A total of 1,057 schools cooperated in the base year; of these, 1,052 schools (815 public and 237 private) contributed usable student data. The sampling frame for the NELS was the school database compiled by Quality Education Data, Inc. of Denver, Colorado, supplemented by racial/ethnic data obtained from the U.S. Office of Civil Rights and school district personnel.

Student sampling produced a random selection of 26,435 8th graders in 1988; 24,599 participated in the base year survey. Hispanic and Asian/Pacific Islander students were oversampled. Within each school, approximately 26 students were randomly selected (typically, 24 regularly sampled students and 2 oversampled Hispanic or Asian/Pacific Islander students). In schools with fewer than 24 8th graders, all eligible students were selected. Potential sample members were considered ineligible and excluded from the survey if disabilities or language barriers were seen as obstacles to successful completion of the survey. The eligibility status of excluded members was reassessed in the first follow-up.

The first and second follow-ups were conducted in 1990 and 1992, respectively, when the cohort was in 10th and 12th grades (approximately 16 and 18 years old). Because of the massive school transfers from middle or junior high schools to high schools, it was impossible to maintain the base year schools sample. Instead, schools were surveyed by tracing students' whereabouts in the follow-up data collection. The resulting student sample, with certain adjustments, continued to be nationally representative of both the 1988 cohort and the student at the given grade; but the high schools in the first and second follow-ups were not representative of the national population of high schools (Ingels & Peng, 1994).

Parents, teachers, and school administrators of the sampled students were also surveyed (Ingels & Peng, 1994). NORC staff administered questionnaire in classrooms to collect student data. For respondents who were absent or dropped out school at the time of survey, data were collected by questionnaire surveys administered off-campus individually or in groups. Data for schools were collected with mailed questionnaires to school administrators.

In each follow-up survey, NORC made sample adjustments to assure (a) that the given round of survey generate data that represent the national student population of the given grade in the give year (called sample freshening) and (b) that the longitudinal sample sufficiently represents the original 1988 8th grader cohort. Students who were selected as freshened sample members in follow-ups (i.e., first-time participants in the NELS) completed a *New Student Supplement*, containing basic demographic items requested in the base year but not repeated in the second follow-up. Dropouts from prior rounds of survey were resurveyed and retested.

In tracing the student sample members, school administrators completed the School Administrator Questionnaire. One mathematics or science teacher completed the Teacher Questionnaire for each student.

In each wave of data collection, a great deal of effort was made to trace those sample members who did not respond to the questionnaire. Survey staff sent cards to remind them after four to six weeks after the response due time. This was followed by telephone calls if the sample member still failed to respond. The unit response rates for the panel data are deemed reasonable (see Table C-1 for missing cases by race-ethnicity and SES. Please note that *all* tables referred to in this study have been placed in Appendix C).

Sample Design

The NELS base year survey included a national probability sample of 1,052 public and private 8th-grade schools in the 50 states and the District of Columbia. Student sampling produced a random selection of 26,435 8th graders in 1988; 24,599 participated. Hispanic and Asian/Pacific Islander students were oversampled. Within each school, approximately 26 students were randomly selected (typically, 24 regularly sampled students and 2 oversampled students). In schools with fewer than 24 8th graders, all eligible students were selected. Potential sample members were considered ineligible and excluded from the survey if disabilities or language barriers were seen as obstacles to successful completion of the survey. The eligibility status of excluded members was reassessed in the first follow-up. The sample was freshened in both the first and second follow-ups to provide valid probability samples that would be nationally representative of 10th graders in spring 1990 and 12th graders in spring 1992. (The Base Year Ineligible Study and the Followback Study of Excluded Students sampled excluded students and added those no longer considered ineligible to the freshened sample of the first and second follow-ups, respectively.) The sample used in the analysis reported here represents the national population of 8th graders in 1988 who went through high school and entered college or the work force.

Appendix A presents a detailed breakdown of the unweighted NELS sample sizes by race-ethnicity, SES, and sex for the descriptive and regression analyses. The descriptive analysis provides a picture of students from 8th grade through 12th grade and thus uses data for students who could be followed from the base year through the second follow-up. The logistic regression analysis, which focuses on S&E major choice, looks at those students who could be followed from 8th grade into a postsecondary institution or the work force; it uses base year through third follow-up data.

Data Components

The base year NELS survey included a student questionnaire and cognitive tests, and parent, teacher, and school administrator questionnaires. The first follow-up survey collected information from students, teachers, and school administrators, but it did not survey parents. The first follow-up also included a dropout questionnaire, the Base Year Ineligible Study, and the High School Effectiveness Study (research on school effects). The second follow-up repeated all components of the first follow-up study and reinstated the parent questionnaire. A new Transcript Study provided archival data on the academic experience of high school students, while a new Course Offerings

Component gathered information on the curricula offered by the schools. The third follow-up study contained only the student questionnaire.

This study used the base year through the second follow-up panel data of public high school students. Students who attended private schools were excluded from the analysis as private education is beyond the scope of this study. Data were extracted from the panel data file so that the resulting statistics project to the national population of students who attended public middle school or juniors high schools of 1988 and who went through secondary schooling in 1992.

Variables in Analysis

The extracted data were edited, re-scaled, or aggregated before model specification and testing. The following is a brief description of the variables that were used in the analysis. See Appendix A for a listing of the relevant data items.

Outcome-oriented EEO. NELS contains three waves of cognitive tests between 1988 and 1992. Each test covered four subject areas: math, science, reading, and history/civic/geography. The analysis used the composite math/reading standardized test score as the indicator of academic achievement in each survey year. Alternatively, the analysis looked at the so-called "cognitive gain" measures derived from the longitudinal test results. Cognitive gain allows the researcher to examine children's cognitive growth based on previous test and specified knowledge proficiency levels. All the test scores are estimates of student academic performance based on IRT modeling, an established statistical estimation technique, to efficiently generate reliable statistics based on sampled data (Ingels & Peng, 1994).

Race-ethnicity and SES. Race-ethnicity information was collected in each round of NELS survey. Composite indicator of race-ethnicity, a better indicator than the raw data item, was created in the Second Follow-up file. It made up nonresponse by using additional information such as school records and parent response. Likewise, SES is a composite score derived from parents' educational attainment, household income, and household valuables during consumer goods. SES is a standardized score with a derived quartile variable, which may be used in descriptive analysis if it is easier to handle in analysis and interpretation. The analysis used the Second Follow-up composite scores for both race-ethnicity and SES.

Computer-based technology access. A series of variables, including home computer ownership and access, school computer access, frequent use of computer, different modes of computer use, computer coursework (literacy, application, and programming), and participation in computer-related enrichment programs.

Other predictor variables. Analysis used a number of school variables relevant to technology access and educational outcomes. These data were collected from school administrators, including: school financial resource, school socioeconomic and racial composition, school geographic locale (urban, suburban, and rural), school average academic performance, and school provision of computer-related programs and facilities.

Data about students' placement in different curricular programs and math and science coursework are available from NELS transcript files. Students self-reported participation in computer-related enrichment activities and personal motivation and educational aspiration. Two teachers who were teaching the surveyed students in the given year were asked about their expectation for students' future education. These data items were edited and examined in the analysis.

Family resource/support were collected in both the student and parent surveys. The analysis ran univariate statistics to examine the data quality and use the better source. The data items may include: parental educational attainment, parents' expectation for the child's education, parent-child joint activities, and home computer ownership. Individual psychobehavioral attributes were in the student survey. Data items included students self-reported parts.

Weighting and Treatment of Missing Data

The complex sample design in NELS requires weighting to compensate estimate bias caused by differential sampling probabilities and response rates. In the descriptive analysis, the base year through second follow-up (BY-F2) panel weight (F2PNLWT) was used to generate estimates; in the logistic regression analysis, the base year through third follow-up (BY-F3) panel weight (F3PNLWT) was used. Because of the stratified, clustered sample design, within-school data were correlated to some extent, and the conventional assumptions of simple random sample were not warranted. Such potential bias, associated with design effects, needs to be taken into account when estimating statistics. The regression analysis used the software package SUDAAN (Shah, Barnwell, & Bieler, 1995), which, with a Taylor series approach, is specifically designed for analyzing data from complex surveys such as NELS.

Missing cases on continuous variables were deleted from both the descriptive analysis and the logistic regression analysis. Missing values on categorical variables were treated differently in the descriptive analysis and logistic regression analysis. In the descriptive analysis, different nonresponses (e.g., don't know, multiple response, refusal, or simply missing) to each categorical variable--with the exception of race-ethnicity--were combined into a single missing category that was not counted in the crosstabulation. In regression analysis, however, cases with such nonresponses to categorical variables were treated differently, depending on the number of missing cases and the meanings of the response categories.

Analytical Methods

The study used descriptive statistical procedures and multiple regression procedures. In the *descriptive analysis*, a large number of variables conceptually relevant to academic achievement and CBT access were examined to determine their psychometric properties and empirical relationships with the outcome variable. This included frequency distribution, univariate statistics, crosstabulation, and comparison of means, with *t*-test or *F*-test. The results from these procedures were a base for selecting variables that were empirically relevant to the research issue for multiple regression analysis.

Multiple regression techniques were then used to examine the predictor variables' unique and joint relationships with academic performance. A series of initial tests were run to explore alternative equations that could yield a reasonably good fit with the data. Particular attention was given to systematic testing of two-way interaction effects in order to detect joint effects of two predictors on majoring in S&E. The tests included interactions between CBT access and race-ethnicity, SES, CBT access and school variables, CBT access and instruction/curriculum variables and teacher's expectation, CBT access and family resource/support, and CBT access and student psychobehavioral variables.

In the final analysis, a series of equations were specified to assess the racial-ethnic and SES gaps in CBT access and the possible generic and differential benefits of CBT on academic performance. The first equation simply demonstrates the existing racial-ethnic and SES gaps in CBT access. Subsequently, school, program, family, and psychobehavioral variables are entered into the equations to estimate how the two gaps might change.

While not strictly statistical, the rationale was that if the race and SES gaps narrowed after entering CBT access indicators, then the hypothesized generic, the effect of CBT access, would be supported. Likewise, other effects of predictor variables that were theoretically responsible for the outcome were examined. The interaction effect, or joint effect between CBT and other predictor variables were estimated by constructing cross-product vectors by multiplying CBT access with other predictor variables. Entering into the equation, the resulting magnitude and statistical significance of these cross-product variables' coefficients would reveal whether there was evidence for hypothesized joint effects.

Limitations

The study may be subject to a number of limits. First, the survey data analysis cannot claim causality among the interested concepts. For example, it cannot ascertain the causal-effect relationship between CBT access and student academic performance. The observational data collected in the longitudinal survey only warranted correlation analysis. Nevertheless, with a sound conceptual framework and significant statistical estimates, the results from the analysis can provide valid information to help learn about the relationship between technological access and educational quality.

Second, the data available from NELS: 88-92 do not represent the most current conditions of technological applicat ion in education. Because the survey covered the period from 1988 through 1992, data that indicate CBT access largely refer to the use of personal computers in school labs, classrooms, and at home. New technologies, such as the Internet, was not as widely accessed in public schools as it is today.

CHAPTER 5

RESULTS AND DISCUSSION

Results

The results are presented in an order corresponding to the research questions and issues posted earlier (see page 8).

Research Issue 1: The Access Gaps

To address the first research issue, Table C-1 (Appendix C) presents the cross-tabulation of computer coursework by race-ethnicity and family income. There was only one statistically significant difference between White (as the reference group) and other racial-ethnic groups: In transcript data on computer science coursework, American Indians and Native Alaskans on average had clearly fewer coursework than Whites (0.35 and 0.54, $p< 0.05$). This difference, however, was not found in self-reported computer coursework. In both self-reported and officially documented coursework, none of other groups differed from Whites. Further, there was no difference in computer coursework across the two income groups. Table C-2 presents the cross-tabulation of mean of reading/math composite score and advanced coursework by race-ethnicity and family income. There were statistically significant differences in reading/math, composite score between White and other racial-ethnic groups (52.6 and 46.38, 44.49, 44.07). Advanced coursework was also statistically significant. Hispanics, Blacks, and American Indians on average had fewer coursework than Whites (4.54 and 2.65, 3.62, 3.74). In income group, still there was a big difference between low-income students and others.

Comparing computer use at home and at school by race-ethnicity and income (see Table C-3), discrepancy emerged. Striking differences occurred across the racial-ethnic groups. In-home computer use, the rates among Whites and Asian and Pacific Islanders (API) were similar as the difference was not statistically significant. The other groups, however, had significantly lower rates than Whites. In particular, the rates for Hispanics and American Indians using home computers were much lower than the rate for Whites (9.56%, 9.45%, and 25.57%, respectively). Blacks also had a lower rate than Whites, but the magnitude of the difference was smaller. Similar racial-ethnic gaps were evident as measured by the frequency of using a computer and the rates of continuous use of a computer in both 10th and 12th grades. Hispanics and American Indians lagged behind Whites in both measures; whereas the Blacks and APIs did not differ from Whites because the rates were not statistically significantly different. Relative to Whites, 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/access. Relative to the others, low-income students consistently had lower rates of using a computer at home and continuous use of a computer in their high school years. And their computer use was less often than the other groups. Both the magnitude and statistical significance level of income-related divide in computer use/access was 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 the actual access of 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 would have strong implications, as was found in subsequent multiple regression analysis.

Research Issue 2: The Generic Benefits of Computer Use

We examined the generic benefit of computer use at home and at school with different variables in relation to math and reading composite score, upon controlling for the effects of variables that have been documented as relevant to achievement (*ceteris paribus* for correlation statements thereafter). In Tables C-4, C-5, and C-6 in percentage/mean of computer access/facility; and percentage of school characteristics by race ethnicity and family income. There were no differences between Whites and other racial ethnic groups at school, students who used computer center/lab, and so on. However, in the multiple regression analysis, there were differences in school CBT access and availability. In Table C-7, with the first equation, we estimated the achievement gaps associated with SES and race-ethnicity. SES is a strong positive predictor of the 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 Whites. The API group had a higher average score than the Whites (with beta= 1.26 and $p<0.05$). Blacks, Hispanics, and American Indians/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 be succinct, we then recoded the race-ethnicity into a single binary variable, which contrasted non-Asian minority groups with Whites and APIs. In equation 2, we entered a set of individual and school background variables that were presumably predictive of achievement, together with SES and the non-Asian minority dichotomy. This procedure allowed us to demonstrate that most background variables were related to achievement, as expected, and then to further test the effects of computer use/access measures after controlling for these background variables.

Specifically, students' strong academic coursework, good sense of self-control, and expectation for college education, were substantially and significantly related to high achievement. Expectation by teachers and parents for the student to go to college was also related to achievement in considerable magnitude. School variables, however, related to achievement in different ways. School rates of students who took free- or reduced-price lunch was moderately related to students' lower achievement level; whereas school rates of minority students and rural locale were found to be unrelated to achievement.

Note that the achievement gaps related to SES and race-ethnicity decreased considerably as those individual and school variables entered into the equation. This implies that those predictor variables accounted for a large portion of the two gaps, meaning that providing the similar conditions on those variables, low-income and minority students, would have done less poorly in math and reading tests relative to Whites and APIs. Also note that the model fit improved as the R^2 for equation 2 more than doubled that for equation 1.

To identify a generic benefit of computer use and access in raising the achievement level, we entered into equation 3 a group of variables measuring computer use and access. Of these variables, only four estimates were statistically significant. Home computer use at 8th grade and continuous use of a computer in the 10th and 12th 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 coursework, as recorded in students' transcripts, was found to relate to low achievement (beta= -1.15 and $p< 0.01$). Counts of using computer in science activities was 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 8th grade, computer availability at school in 8th grade, teacher reported computer active use in school, advanced computer program courses provided-10th grade, and self-reported computer coursework in 10th grade) was found to be associated with achievement.

While these findings raised more questions than answers, a rough pattern, nevertheless, was discernible: computer use in high school did not help improve academic achievement, whereas computer use at home and persistently throughout secondary school years was associated with better achievement. This pattern confirms earlier studies that documented the importance of computer use at home because it boosts children's interest, self-confidence, as well as increase skills in using a computer at school for academic learning (Gladioux & Swail, 1999).

Research 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-8 shows multiple regression coefficient estimates for comparison of non-Asian minorities and APIs against Whites and of the low-SES group (defined by the lowest quartile of the SES composite score) against the group 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, 10th graders' expectations to college education, rural school, parents' expectations for students' college education.

Remarkably, a number of computer-relevant variables differed in their relation to achievement across the two groups. Home computer use did not make a difference among minority students; it related to higher achievement only among the Asian and Whites (beta= 0.89 and $p<0.01$). Similarly, continuous computer use made no difference among minorities, but it related to achievement (beta=1.03 and $p<0.01$) for White and API students. Further, self-reported computer course credits did not relate to achievement of minority students, yet it negatively related to achievement of Asian and White students. Conversely, using a computer in science activities was not associated with achievement of Asians and Whites, but it did negatively, albeit weakly with that of minorities (beta=-0.17 and $p<0.05$). Note that transcripts documented computer science credits were consistently related to *low* test scores for both groups.

The low-SES group also differed in estimates for computer-related variables from the other SES groups. Home computer use and continuous computer use in high school years both were unrelated to achievement of low-SES students yet moderately and positively related to achievement of other SES group (with beta values of 1.03 and 0.98, respectively, and both significant at the $p<0.01$ level). Thus, the generic effects of these two indicators of computer access/use shown in Table C-3 did not hold for either minority or low-SES students. They only reflected the positive effects among the non-disadvantaged population. In other words, using a computer at home or at school in high school years did not seem important in improving minority and low-income students' academic performance. The model for low-SES group yielded a smaller R^2 than did the model for other groups (0.39 and 0.52, respectively), suggesting that there should be more factors at work than what we had in the equation for explaining the variation of the low-SES group's test scores.

Additionally, we tested potentially most interesting joint effects or interaction effects in the equations. We constructed four cross-product variables that represented the joint effects of (a) SES and home computer use, (b) SES and continuous computer use, (c) non-Asian minority and home computer use, and (d) non-Asian minority and continuous computer use. Controlling for all the predictor variables in equation 3 of Table C-3, we added the interaction effects into the equation (see Table C-9). None of the interaction indicators yielded statistically significant estimates. There was no evidence that computer use--with indicators that were reasonably well related to achievement--benefited a particular income or racial-ethnic group more than the rest of the population. At least with the NELS data that reflected early 1990s condition of computer application in education, we could not provide a clear answer to the question.

Research Issue 4: The Gap-Reduction Effect

How does computer use/access help narrow achievement gaps associated with income and race-ethnicity? With home computer use at the 8th grade, an indicator of computer use that was found to positively relate to achievement, we could distinguish the NELS respondents into two groups. A majority group (n=7,494) was students who did not use a computer at home and another group (n=2,218) was those who did. 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. In Table C-10, the estimates from the two equations were compared. Among students who did not use a computer at home, the achievement gap associated with SES did not differ much from that among students who did use a computer at home. But the gap relating to race differed substantially: it was larger among those who used a computer at home (with beta values of -2.66 and –3.75, respectively, both significant at the $p<0.01$ level). In other words, other things being equal, the difference in performance between minorities and their White and API peers was larger if both groups used a computer at home in the early secondary school age, relative to the difference between the two groups if they did not use a computer at home. In other words, computer use at home did not narrow the racial-ethnic gap in achievement.

On the other hand, using a computer at home seemed to relate to a slightly lower effect of students' advanced coursework and the locus of control on achievement. The two estimates were smaller for the group that used a computer at home than they were for the group that did not. Also, using a computer at home rendered the negative effect of school minority rates statistically insignificant. This finding is interesting in contrast with the increased magnitude of the estimate for non-Asian minority groups.

Among students who used a computer at home, educational expectation seemed more predictive of the achievement than it was among students who did not. This included the three variables on expectation by parents, teachers, and the students themselves. The magnitudes of the three estimates were consistently larger for the group that used a computer at home than in the group that did not. Moreover, the estimate for continuous use of computer in 10th and 12th grades also was large and statistically significant for the group that used computer at home (beta=1.61 and $p<0.01$), but not so in the other group.

There are other noteworthy findings in Table C-10. The frequency of using computer in science activities was negatively related to achievement for the group that did not have computer at home (-0.14; significant at $p<0.01$ level); whereas no such relationship was observed in the group that used computer at home. The negative relationship between computer science credits (in transcripts) and achievement, however, was consistently negative for the two groups.

Research 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 lunch. Another set represented school learning environment factors, including two indicators: the provision of advanced computer program courses and the teacher's 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 of rural schools versus students of other locale). 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 for.

In Table C-11, we present the results of regression equations for subgroups on school demographic variables. Comparing students of rural schools with students of other locales, home computer use did not relate to achievement among rural students (the estimate, 0.43, was not statistically significant), though it did among students in schools elsewhere (beta =1.16 and $p<0.01$). This is the only indicator of computer use that showed a difference across the subgroups of locale.

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 at both 10th and 12th grades did not relate to achievement for students of schools with high minority rates, but it did fairly strongly for students of other schools (beta=1.25 and $p<0.01$). The pattern seems that computer use *at home* benefited students going to schools of high-minority rates more than it did for students going to schools of low-minor ity rates. However, using a computer continuously during high school years only benefited students who went to schools of low-minority rates.

There was a milder difference between the two groups: student self-reported computer coursework was negatively related to achievement only of students attending schools of low-minority rates (beta = -0.17, $p<0.05$), not of students attending school of 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 10th and 12th grades related to higher achievement only among students of low-poverty schools, not those of high-poverty schools.

Achievement was negatively related to computer science courses (recorded in transcripts); and 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 of different minority rates.

Table C-12 presents the estimates from four equations for subgroups based on school's learning environment. Again, the two indicators of computer use, using a computer at home and continuous computer use through high school years, appeared to differ in relationship to achievement between the subgroups. For students whose teacher expected them to go to college, home computer use was related to higher achievement (beta=1.12 and $p<0.01$); whereas for students whose teacher did not expect so, there was no such relationship. On the other hand, the positive relationship between achievement and continuous computer use for students whose teacher did not expect them to go to college seemed stronger than for students whose teacher expected so (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 school provided advanced computer program courses, home computer use was not related to achievement; whereas 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-13).

Research Issue 6: The Technology-Individual Interaction Effects

With the same approach 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-14, Appendix C).

Among students who expected themselves to go to college, home computer use was strongly and statistically significantly related to greater academic achievement (beta=1.01 and $p<0.01$); whereas 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 10th and 12th grades, however, did not reveal such a clear pattern. The estimates were positive and statistically significant in both models, with some differences in the magnitude and the significance level. Also, computer course taking and using computer in science activities were both negatively associated with achievement for both groups.

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-15).

Discussion

Issue 1: The Access Gaps

This analysis allowed us to highlight several interesting patterns in which computer use relates to academic achievement gaps across race-ethnicity and SES. First, the difference in computer availability and access was substantially larger across income levels, not across race-ethnicity.[2] Students from a low-income background on average were less likely to access a computer. They took, however, no fewer computer courses than other students. Across race-ethnicity, Hispanic and

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[2] Wenglinsky (1998), in analysis of the National Assessment of Educational Progress data, found that Black students tended to report more frequent computer use than White students, but noted the qualitative difference in computer use across groups.

Native Americans were found to be disadvantaged in some measures of access; but again, they took no fewer computer courses than the other students. A clear distinction across both race-ethnicity and SES categories was in computer use at home. High-income, White and Asian students rated much higher than low-income and minority subgroups. This general pattern seems compatible to prior studies that documented the shrinking technological access gap, but pointed at the discrepancy in home computer ownership and use.

Striking differences were found among racial-ethnic groups when computer use at home and at school was compared by race-ethnicity and income. We found evidence that supported the notion of a "digital divide" relating to race-ethnicity and income. The difference was especially clear with data that indicate the actual access of computers, 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. With indicators of access and use at school, the difference was more substantiated between income groups than among racial-ethnic groups.

Issue 2: The Generic Benefits of Computer Use

It was found that computer use at home was related to better test scores; but access and use of a computer at school did not appear helpful to improving achievement. Using a computer persistently in high school years was also found to be associated with better achievement. These two findings are important as they confirmed the ramification role of home computer ownership and access. However, the effects of these two indicators of computer use did not hold for either minority or low-SES students. They only reflected the positive effects among the non-disadvantaged population. Using a computer at home or at school in high school years did not seem important in improving minority and low-income students' academic performance. Home computer use at 8th grade and continuous use of computer in 10th and 12th grades were found to be significantly related to high achievement. However, computer science coursework, as recorded in students' transcripts, was found to relate to low achievement, and computer use in high school did not help in improving academic achievement. It was not clear as to why and how computer use in school did not function well to help learning.

Surprisingly, holding other variables constant, students who took computer science courses even had lower average math and reading test scores--a finding that we repeatedly confirmed in analysis. For virtually all subgroups we examined in separate analyses, this variable related to low test scores in a moderate degree. It was not clear, however, why and how computer use in school did not function to help learning. New technologies, such as the Internet, were not as widely accessible in public schools as they are today. Software, hardware, and computer usage, while growing, was not as prevalent in the 1980-1990 time frame, particularly within the youngest and oldest population segments (Liu, 1997). When it came to actual teaching and using the computer in the classroom, "The prevalent view of computers for the classroom still seems to be one in which the computer 'teaches' by controlling information and managing student efforts. Such uses limit rather than expand children's possibilities for learning" (Bruce, 1984, p. 38). Teachers during that time just taught students basic functions, like using a calculator. As Bruce pointed out, "computers are seen as useful solely for teaching specific concepts or skills: punctuation, spelling, simple arithmetic calculations, etc., or for managing the process of instruction." (p. 38). Little did they know what new software, the Internet, ASP, and broadband availability would do to change the common conception of computer usage. During the most recent period, 1990- 2000, Multimedia development, audio, video, and streaming media have exploded in terms of popularity and usage. All age groups now quite naturally turn to their computers for many aspects of daily living (i.e., travel plans, email, market research, games, auctions, purchasing, etc.).

Currently, the biggest impact of computers in classroom is in terms of ways that multimedia technology and the computer can be applied to enhance learning and teaching. Recently, teachers have become very interested in learning the means to integrate technology with learning systems in classrooms settings (Windschitl, & Sahl, 2002). As the teachers become more comfortable with the "how to" aspects of modern computer usage, relative to their teaching methods, their students in turn will greatly benefit by understanding how creativity can be applied to their study disciplines and workloads; while also being stimulated during the learning process because teachers will be confident in creating multi-media environments with which to pique their students' interest and gain lengthier attention spans. "Teachers' beliefs about learners and learning, which are mediated by the specific character of the school community and the host of informal ways in which teachers learn to use technology" (Windschitl & Sahl, 2002, p. 203). The "engaged" teacher can use technology to help students become more creative in their approach to issues, as well as maintaining their curiosity as to what they can do individually to compete against their peers in a positive manner. If games can occupy the time, mind, and hearts of students, it is also possible for the teacher to use methods that will compete effectively for the students' attention.

New term technology improvements can also be utilized to include video-conferencing, flash images, streaming video, personal ASP, individual home pages, instant messaging, imported programming, and the list goes on and on. Since business has imported this new technology and brought their business acumen to new levels, so teachers and students must also keep up with the latest developments in order to compete for a job within the current very competitive job marketplace. Teachers should avail themselves of every opportunity to use New Age tools to upgrade their expertise and provide a more satisfying environment for their students. Disadvantaged and minority populations also stand to gain by accepting their responsibility to seek out and assimilate those assets that can best be incorporated into job interviews and job retention. While suggestive explanations could be offered, this finding called for serious research into the process and mode of computer science instruction and curriculum.

Issue 3: The Differential Benefits

Home computer use did not make a difference among minority students. It related to higher achievement only among Whites and APIs. Similarly, continuous use made no difference among minorities, but it related quite strongly to achievement for Whites and APIs.

The low-SES group also differed in estimates for computer-related variables from other SES groups. Home computer use and continuous computer use in high school years were unrelated to achievement of low-SES students, yet moderately and positively to achievement of other SES groups (literature). Our finding indicated that the generic effects of computer use/access did not hold for either minority or low-SES students.

Issue 4: The Gap-Reduction Effect

Among students who did not use a computer at home, the achievement gap did not differ much from that among students who used a computer at home. Perhaps it implies that while accessing computer at home did not help minority children improve test scores, the access might help alleviate the disadvantage imposed by a minority-concentrated school setting.

This finding suggests that academic performance of students who had a computer at home is positively related to continuous computer use, but this relationship is not clear among students who did not have a computer at home.

Issue 5: The Technology-School Interaction Effects

On the other hand, we found that students who took computer courses had *lower* average test scores--given other things are equal. In addition, a number of indicators of computer use and access were not important in relating to academic achievement. Such findings were quite consistent in the separate analyses of subgroups. It should not be entirely surprising, however, as prior studies had raised the issue that computer courses could be mediocre in intellectual quality and the mere access can be of little use (e.g., Warschauer, 2000). Perhaps, computer education programs--at least in early 1990s--were not thoughtfully designed and effectively delivered. Instead, as sort of the substitute for challenging academic programs, computer courses were provided merely for occupational or technical training. While awaiting additional research into the processes of computer instruction, we reiterate the questions regarding the importance of applying computers and other technologies in academic programs for genuine cognitive growth of all children.

Ironically, computer courses offered in the early 1990s--perhaps not of high quality--tended to only reduce the performance of students who attended average high schools, but not those in minority-dominant schools.

Issue 6: The Technology-Individual Interaction Effects

Among students who expected themselves to go to college, home computer use was strongly and statistically significantly related to greater academic achievement, whereas among students who did not expect a college education, the coefficient was small and not statistically significant. This finding supports the notion that students benefit from using computer if they have higher expectation in education.

Individual group differences were found to relate to use of a computer and achievement. For example, a home computer was related to superior achievement for students who took advanced courses, but not for students who did not. Among students who took advanced courses, favorable test scores were related to continued computer use, but the relationship did not occur among students who did not take advanced courses. This seemed to suggest that students who are highly motivated tend to take advanced courses, which in turn affect their decision to continue to use a computer and, eventually, their achievement in test scores.

Note that the subgroup without advanced credit was small (n=346), which might have partly caused statistically insignificant estimates for the group. For example, none of the variables of college expectation (by students, parents, and teachers) produced a significant estimate for the group, in contrast to the significant estimates for the other group. Further, there was no racial-ethnic difference among the small group that earned no advanced credits, whereas this difference clearly existed in the other group (and in previous analyses). This finding, while relating to the small sample size, may reflect some genuine attributes of the group whose members were presumably more homogeneous than the large group.

Summary

The analysis of the NELS data, adjusted for a series of individual and school background factors, generated the following findings:

1. Compared with their peers, disadvantaged children (defined as children of racial-ethnic minorities other than Asian and Pacific Islanders and children of low-socioeconomic status) did not lag far behind in computer use at school, but they did lag behind in computer use at home.

2. Computer use at home was far more significant than computer use at school in relating to high academic performance, but this effect was absent for minority and low-SES children.

3. Using computers at school seemed to have dubious effects on learning: taking computer science courses at school consistently related to low performance for both the disadvantaged and the other children.

4. Disadvantaged children benefited less than other children from using computer as indicated by various variables, including that for using computer at home.

5. Relative to their peers, disadvantaged children's academic performance seemed less predictable by computer use and other independent variables.

In short, we have failed to observe a generic benefit of computer use with the NELS data. Computer use at school did not appear helpful to elevate achievement. Home computer use, an opportunity that is largely determined by family socioeconomic and cultural resources, was related to higher test scores. Furthermore, such apparently socially differentiated access did not work for all. The effect did not hold for minority and low-SES students. Using computers at home only functioned to enhance learning among more fortunate children. In our analysis, using computers at home or at school in high school years did not seem important in accounting for minority and low-income students' academic performance.

These findings support the notion that seemingly ubiquitous computer-based technologies are nevertheless differentially available and functioning by social and demographic groups. Public education has not remedied the problems imposed by the social stratification of technologies. The findings refute the over-simplistic belief that application of technology could benefit all children in public schools by closing achievement gaps.

This analysis seems to underscore a need for reform of technology policies and computer-related curricula/instruction to provide equitable education for all children. The pattern that computer science classes in general were related to low achievement points to the possibility that ill-designed curriculum or poor instruction rendered such technology-oriented programs disappointing. Also, achievement gaps--irrelevant of a number of variables of computer use at school or home setting--suggest that technologies per se may not work to help performance. Technologies alone would not work well for closing achievement gaps, especially since the performance of minority and poor children was related to computer use only to a limited extent.

These finding should not be entirely surprising, however, as prior studies have raised possibilities that computer courses could be mediocre in quality and that mere access to technologies was of little value (e.g., Warschauer, 2000). Perhaps, computer education programs--at least in early 1990s--were not thoughtfully designed and effectively delivered. Worse yet, computer courses might have been provided in some schools as a substitute for challenging academic courses. While awaiting additional inquiries into the contents, process, and mode of computer instruction, we reiterate the questions regarding the importance of applying computer and other technologies in academic programs for genuine cognitive growth among all children.

CHAPTER 6

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 did 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 lack of affluence providing them with 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 is at its most constructive benefit if students are given clear expectations by teachers. The evidences from this study also support the claim that both the students' motivation and the teachers' expectation are the key to students' success in academic performance. Specifically, the students whose teachers expected them to go to college fare 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 to work independently to achieve clearly defined course objectives. It is paramount that the teacher establish standards and high expectations as well as encouraging creativity, determination, and the ability to perform research with computer technology. The student should be motivated to incorporate the computer into their daily life as a means of achieving a higher SES. Special attention needs to be given to teaching strategies involving the computer, as well as encouraging 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 expectation.

Students participating in computer science courses displayed lower average math and reading test scores which poses a number of causal relationships. Are students getting lazy because the computer performs so many functions for them, or does the time devoted to this new class of subjects take away from the time formerly available to pursue the traditional 3Rs, or has teachers' education ability deteriorated due to lower entry standards and professional achievement, or 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 process and technique of computer science instruction and curriculum. 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 each and every subject they teach. Current methods demonstrably are not working in the sense of making progress in the learning process. Policies and curriculum must be developed which 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 is as important as socioeconomic factors in determining the level of SES achievement by the career graduate. Increased access to computers will only have positive results when the educator has a complete grasp of the role and use of computers, and an understanding of the student's home environment and how their deficiencies must be met in order to realize their full potential, thus enhancing society instead of reducing the average achievement.

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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 F2 Cognitive Test by Sex, Race/Ethnicity, and SES Quartile: Unweighted NELS BaseYear-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[a]				
Male	8,140	6,284	22.8%	52.13
Female	8,349	6,430	22.9%	51.05
RACE/ETHNICITY				
Asian and White	12,657	9,935	21.5%	53.16
Black, Hispanic, 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

Note. 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 9 cases with missing information on race/ethnicity. [b]There is 1 case with missing information on SES

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	Maxi-mum
F12XCOMP	STNDRDIZED TEST COMPOSITE (READINGMATH)	9924	50.88	9.63	30.27	71.29
F22XCOMP	F2 STD TEST COMP (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
LOCUSCTR	COMBINE BYF1 LOCUS CONTRL SCR	9915	0.03	0.71	-3.01	1.52
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
Categorical Variables (binary variables are coded 1 and 2)						
HMCOMPUT	HOME COMPUTER USE BASEYEAR	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
F1ADVCBT	F1SCH HAD ADVANCE PCPRGRM COURSES	9924	1.14	0.35	1	2
F2RACE2	Asian Pacific Islander	9924	1.03	0.17	1	5
	BlacK	9924	1.10	0.30	1	
	HispaniC	9924	1.13	0.34	1	
	WhitE	9924	1.73	0.45	1	
	NativE	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
RURAL	RURAL SCHOOL	9924	1.36	0.48	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	TCHER EXPECT R COLLEGE	9924	1.57	0.50	1	2

Note. 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.

APPENDIX C

TABLES

Table C-1

Computer Access/Use Gaps: Means of Computer Courses by Race-Ethnicity and Low-Income Status Subgroups of 1992 Seniors

Subgroup	Units in computer science (transcripts)	Self-reported computer courses
White	0.54 (0.02)	0.77 (0.04)
Asian and Pacific Islander	0.58 (0.04)	0.98 (0.10)
Hispanic	0.63 (0.05)	0.78 (0.07)
Black, non-Hispanic	0.56 (0.05)	0.97 (0.10)
American Indian/Native Alaskan	0.35 (0.06)*	0.70 (0.16)
Others	0.56 (0.02)	0.81 (0.04)
Low-SES students	0.52 (0.03)	0.77 (0.05)

Note. Standard errors in parentheses. Data weighted in this and all subsequent procedures by the relative panel weight (the By-F2 panel weight F2PNLWT divided by its mean). From U.S. Department of Education, National Center for Education Statistics, National Education Longitudinal Study of 1988-1992 (NELS:88), "Base Year" through "Second Follow-up" panel data.

* $p < 0.01$, with T-test of the null hypothesis that the subgroups' means do not differ (the contrast is White in race-ethnicity comparison).

Table C-2

Achievement Gaps: Means of Reading/Math Composite Score and Advanced Coursework by Race-Ethnicity and Low-Income Status Subgroups of 1992 Seniors

Subgroup	Reading/math composite score[a]	Advanced coursework[b]	Locus of control scores[c]
White	52.06 (0.20)	4.54 (0.07)	0.08 (0.01)
Asian and Pacific Islander	53.72 (0.61)*	6.06 (0.19)*	-0.01 (0.05)
Hispanic	46.38 (0.38)*	3.74 (0.13)*	-0.08 (0.05)*
Black, non-Hispanic	44.49 (0.46)*	3.62 (0.16*	-0.11 (0.04)*
American Indian/Native Alaskan	44.07 (1.66)*	2.65 (0.37)*	-0.23 (0.15)
Others	52.32 (0.19)	4.83 (0.07)	0.09 (0.01)
Low-income students	44.96 (0.26)*	2.96 (0.08)*	-0.14 (0.03)*

Note. Standard errors in parentheses. From National Education Longitudinal Study of 1988-1992 (NELS:88).

[a] Standardized score at 12th grade. [b] Including foreign language, precalculus, calculus, trigonometry, biology, chemistry, physics, and computer science. [c] Measured in 10th grade, but the missing values were substituted with 8th grade measure.

* $p < 0.01$ with *T*-test of the null hypothesis that the subgroups' means do not differ (the contrast is white in race-ethnicity comparison).

Table C-3

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

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]
White	25.57% (0.88)	19.33%(0.69)	1.23 (0.03)	7.13 (0.05)
Asian and Pacific Islander	31.37 (2.91)	23.7 (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)*
Black, 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 in parentheses. From U.S. Department of Education, National Center for Education Statistics, National Education Longitudinal Study of 1988-1992 (NELS:88), "Base Year" through "Second Follow-up" panel data.

[a] A scale with counts of activities where computer was used, derived from four items in the First Follow-up data (S29H, F1S29I, F1S29J, and F1S29K). [b] Combined two scales ranging from 1 through 5 indicating increasing frequency of computer in 10th and 12th grade, respectively; see Appendix B for labels.

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

Table C-4

School Reported Computer Access/Facility Gaps: Percentage of Computer Access/Facility by Race-Ethnicity and Low-Income Status Subgroups of 1992 Seniors

Subgroup	By school CBT active access %	By school CBT availability %	Teacher say CBT active use %	School computer lab available %
White	31.92% (1.34)	76.84% (1.96)	2.93% (0.05)	59.88% (2.35)
Asian and Pacific Islander	32.35 (2.96)	81.11 (3.34)	3.43 (0.94)	64.36 (4.85)
Hispanic	36.98 (3.32)	75.31 (4.15)	1.33 (0.55)	64.79 (4.56)
Black, non-Hispanic	33.46 (2.62)	77.17 (3.54)	1.72 (0.61)	67.65 (3.93)
American Indian/Native Alaskan	40.20 (6.32)	84.67 (4.68)	7.38 (6.07)	36.91 (11.37)
Others	33.12 (2.48)	77.07 (3.52)		
Low-income students	36.12 (3.30)	76.80 (1.94)		

Note. Standard errors in parentheses. From National Education Longitudinal Study of 1988 (NELS:88).

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

Table C-5

School Reported Computer Access/Facility Gaps: Percentage/Mean of Computer Access/Facility by Race-Ethnicity and Low-Income Status Subgroups of 1992 Seniors

Subgroup	F1 sch had adv PC program CRS %	Students who used computer center/lab	Graduation requirements for computer education
White	13.79% (1.43)	3.86 (0.06)	1.28 (0.03)
Asian and Pacific Islander	23.69 (3.29)*	3.76 (0.12)	1.30 (0.06)
Hispanic	11.90 (2.76)	3.52 (0.14)	1.57 (0.11)
Black, non-Hispanic	14.37 (3.10)	3.52 (0.12)	1.29 (0.07)
American Indian/Native Alaskan	7.08 (3.70)	3.45 (0.62)	1.03 (0.30)
Others		3.83 (0.06)	1.29 (0.03)
Low-income students		3.63 (0.08)	1.32 (0.05)

Note. Standard errors in parentheses. From National Education Longitudinal Study of 1988 (NELS:88).

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

Table C-6

School Characteristics: Percentage of School Characteristics by Race-Ethnicity and Low-Income Status Subgroups of 1992 Seniors

Subgroup	Urban %	Rural school %
White	15.53% (1.46)	39.32% (2.21)
Asian and Pacific Islander	33.69 (4.06)*	13.48 (2.15)*
Hispanic	44.55 (4.54)*	25.18 (4.71)
Black, non-Hispanic	42.00 (4.04)*	30.05 (3.55)
American Indian/Native Alaskan	18.42 (6.27)	53.28 (11.06)
Others	21.48 (1.66)	33.02 (1.94)
Low-income students	25.42 (2.21)	45.11 (2.55)

Note. Standard errors in parentheses. From National Education Longitudinal Study of 1988 (NELS:88).

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

Table C-7

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

Predictor variables	Equation 1: SES and race–ethnicity gaps	Equation 2: SES and racial-ethnic gaps net of backgrounds	Equation 3: Generic benefit of computer access/use
SES Composite	5.07 (0.17)**	1.10 (0.16)**	0.85 (0.17)**
Race–ethnicity			
Non-Asian minorities vs. White	--	-3.10 (0.30)**	-2.91(0.29)**
Asian Pacific Islanders vs. White	1.26 (0.55)*	--	--
Hispanic vs. White	-2.16 (0.45)**	--	--
Black vs. White	-5.08 (0.44)**	--	--
American Indian/Alskan vs. White	-4.85 (1.27)**	--	--
Advanced high school courses		1.52 (0.06)**	1.65 (0.06)**
Locus of control 8th-10th grade		1.40 (0.15)**	1.36 (0.15)**
School % of minorities		-0.13 (0.07)	-0.15 (0.07)*
School % of free lunch		-0.19 (0.08)*	-0.15 (0.08)*
Rural school		0.24 (0.24)	0.42 (0.25)
Teacher expect student to go to college		1.92 (0.25)**	1.93 (0.24)**
10th grader expect to go to college		1.72(0.25)**	1.60 (0.25)**
Parents expect student to go to college		1.52 (0.24)**	1.29 (0.24)**
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 active 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)**
Self-reported computer coursework-10th grade			-0.14 (0.07)
Intercept	51.70	44.88	47.76
R^2	0.24**	0.54**	0.54**
Number of parameters	6	11	20
Number of cases (weighted)[a]	9,924	9,916	9,712

Note. Standard errors in parentheses. 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] The number of cases changed across equations due to list-wise deletion of missing cases.

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

Table C-8

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	APIs and Whites	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)
Rural school	-0.43 (0.49)	0.63 (0.28)*	0.42 (0.45)	0.41 (0.27)
Teacher expect student to go to college	1.68 (0.52)**	1.98 (0.26)**	2.02 (0.46)**	1.98 (0.28)**
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 at school 8th grade	-0.25 (0.46)	0.01 (0.24)	0.07 (0.43)	0.02 (0.25)
Computer available at school 8th grade	0.04 (0.57)	-0.40 (0.31)	0.50 (0.42)	-0.21 (0.31)
Use computer in science activities	-0.17(0.05)**	-0.07 (0.05)	-0.13 (0.07)*	-0.09 (0.05)
Teacher reported active computer use in school	0.06 (0.86)	0.44 (0.60)	-0.51 (1.36)	0.42 (0.58)
Advanced computer program course provided at school 10th grade	0.67 (0.55)	0.47 (0.35)	0.22 (0.77)	0.48 (0.33)
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 in parentheses. 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.

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

Table C-9

Examining Differential Benefit of Access to and Using Computer by Race-Ethnicity and SES: Multiple Linear Regression Interaction Effects Estimates

Interaction effects[a]	Coefficient estimate[b] (standard error)
Non-Asian minority X home computer use-Base Year	0.24 (0.66)
Non-Asian minority X use computer both 10th and 12th grade	0.82 (0.69)
SES X home computer use--Base Year	0.01 (0.30)
SES X use PC both 10th and 12th grade	0.33 (0.34)

Note. Standard errors in parentheses. 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] Interaction effects are presented after controlling for all of the independent variables in Equation 3 of Table C-3. [b]None of the interaction effects is statistically significant at $p<0.05$ level.

Table C-10

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. Whites	-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 used 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-transcripts	-1.07 (0.19)**	-1.48 (0.23)**
Self-reported computer coursework-10th grade	-0.12 (0.09)	-0.13 (0.10)
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 in parentheses. 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.

* p<0.05. ** p<0.01.

Table C-11

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

Predictor variables	Students of rural schools	Students of other locales	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	-3.05 (0.52)**	-2.70 (0.36)**	-2.97 (0.49)**	-2.89 (0.34)**	-3.04 (0.45)**	-2.75 (0.37)
SES Composite	0.81 (0.19)**	0.86 (0.23)**	0.76 (0.34)*	0.83 (0.17)**	0.90 (0.28)**	0.79 (0.19)**
Advanced high school courses	1.67 (0.10)**	1.61 (0.06)**	1.72 (0.12)**	1.60 (0.06)**	1.68 (0.12)**	1.62 (0.06)**
Locus of control 8th & 10th grade	1.02 (0.23)**	1.55 (0.18)**	1.56 (0.32)**	1.25 (0.16)**	1.55 (0.25)**	1.20 (0.17)**
School % minority	-0.28 (0.11)*	-0.07 (0.10)	–	–	-0.14 (0.10)	-0.12 (0.09)
School % free lunch	-0.21 (0.14)	-0.15 (0.10)	-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	1.45 (0.38)**	1.74 (0.31)**	1.14 (0.51)*	1.84 (0.26)**	1.87 (0.42)**	1.50 (0.29)**
Parent expect student to go to colg.	1.79 (0.36)**	1.02 (0.30)**	0.52 (0.46)	1.56 (0.27)**	0.27 (0.37)	1.82 (0.30)**
Teacher expect student to go to colg.	1.74 (0.34)**	1.99 (0.32)**	1.61 (0.54)**	2.00 (0.26)**	1.92 (0.42)**	1.92 (0.29)**
Home computer use 8th grade	0.43 (0.34)	1.16 (0.25)**	1.21 (0.57)*	0.79 (0.21)**	1.45 (0.41)**	0.71(0.22)**
Computer use in both 10th and 12th grade	1.09 (0.38)**	1.01 (0.33)**	0.01 (0.54)	1.25 (0.28)**	0.09 (0.43)	1.32 (0.30)**
Use computer at school 8th grade	-0.26 (0.34)	0.20 (0.27)	0.19 (0.45)	-0.01 (0.24)	0.35 (0.36)	-0.07 (0.26)
Computer available at school 8th grade	-0.27 (0.41)	-0.30 (0.37)	0.11 (0.56)	-0.48 (0.31)	0.31 (0.46)	-0.40 (0.34)
Computer use in science activities	-0.14 (0.06)*	-0.21 (0.04)**	-0.23 (0.05)**	-0.16 (0.04)**	-0.23 (0.04)**	-0.15 (0.05)**
Teacher reported computer active use in school	1.42 (0.92)	0.20 (0.60)	1.52 (1.35)	0.19 (0.58)	0.39 (1.28)	0.32 (0.56)
Advanced computer program courses provided 10th grade	0.28 (0.51)	0.41 (0.33)	-0.24 (0.58	0.26 (0.34)	0.02 (0.55)	0.38 (0.34)
Computer science coursework – transcripts	-0.94 (0.23)**	-1.31 (0.19)**	-0.90 (0.31)**	-1.26 (0.17)**	-0.96 (0.25)**	-1.32 (0.18)**
Self-reported computer coursework 10th grade	-0.15 (0.10)	-0.08 (0.10)	0.06 (0.14)	-0.17 (0.08)*	-0.03 (0.12)	-0.17 (0.08)
Intercept	48.51	48.32	47.44	48.60	46.46	48.83
R^2	0.53**	0.56**	0.50**	0.53**	0.52**	0.53**
Number of parameter	19	19	19	19	19	19
N of weighted cases	3,514	6,198	2,329	7,383	3,113	6,599

Note. Standard errors in parentheses. 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-lunch: schools with a rate higher than 30% are defined as high poverty, otherwise are low poverty. Data were weighted by the relative panel weight (the By-F2 panel weight F2PNLWT divided by its mean).

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

Table C-12

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

Predictor variables	Students whose teacher expect them to go to college	Students whose teacher did not expect them to go to college	Students whose school provide advanced computer courses	Students whose school provide 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)**
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 porgram 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)**
Self-reported computer coursework 10th grade	-0.09 (0.09)	-0.17 (0.12)	-0.07 (0.16)	-0.12 (0.08)
Intercept	48.79	46.22	50.15	47.99
R^2	0.44**	0.39**	0.57**	0.54**
Number of parameter	19	19	19	19
Number of weighted cases	5,653	4,059	1,375	8,336

Note. Standard errors in parentheses. 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).

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

Table C-13

Differential Benefits Test With Interaction Effects Between School Factors and Access to and Using Computer: Multiple Linear Regression Interaction Effects Estimates

Interaction effects[a]	Coefficient estimate[b] (standard error)
Advanced coursework X home computer use at 8th grade	-0.14 (0.07)*
Advanced coursework X using PC both 10th and 12th grade	-0.02 (0.08)
Rural school X home computer use at 8th grade	0.51 (0.44)
Rural school X using PC both 10th and 12th grade	-0.45 (0.44)
School % minority X home computer use at 8th grade	0.25 (0.11)*
School % minority X using PC both 10th and 12th grade	-0.21 (0.11)
School % free lunch X home computer use at 8th grade	0.19 (0.11)
School % free lunch X using PC both 10th and 12th grade	-0.17 (0.13)
Teacher expected student to go to college X home computer use at 8th grade	0.47 (0.47)
Teacher expected student to go to college X using PC both 10th and 12th grade	-0.55 (0.52)

Note. Standard errors in parentheses. 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] Interaction effects are presented after controlling for all of the independent variables in Equation 3 of Table C-7. [b] None of interaction effects is statistically significant at $p<0.05$. level.

* $p<0.05$.

Table C-14

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

Predictor variables	Students who expect themselves to go to college	Students who did not expect themselves 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)
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 parameter	19	19	19	19
N of weighted cases	4,836	3,875	9,365	346

Note. Standard errors in parentheses. 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] This subgroup did not have any credits in computer science coursework, as the group definition implies.

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

Table C-15

SES and Racial–Ethnic Gaps in Math and Reading Composite Test Score: Interaction Effects Between Student Individual Factors and Access to and Using Computer: Multiple Linear Regression Interaction Effects Estimates

Interaction effects[a]	Coefficient estimate[b] (standard error)
Locus of control X home computer use at 8th grade	-0.09 (0.31)
Locus of control X using PC both 10th and 12th grade	-0.19 (0.33)
Student expectation for college education X home computer use at 8th grade	-0.47 (0.47)
Student expectation for college education X using PC both 10th and 12th grade	0.29 (0.56)

Note. Standard errors in parentheses. SOURCE: 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] Interaction effects are presented after controlling for all of the independent variables in Equation 3 of Table C-7. [b] None of interaction effects is statistically significant at the $p<0.05$ level.

VITA

Jianxia Du was born on December 3, 1955, in Chongqing, China. She received her BPED. degree in Education from Southwest Teachers College, China, in 1987. She taught high school students and undergraduates for 5 years. Since 1996, she attended the University of Illinois at Urbana-Champaign where she earned her Master of Art's degree in Education and her Ph.D., specializing in Educational Policy and Educational Technology. At UIUC, she served as a research assistant and teaching assistant for Professor James Anderson for six years.

Jianxia has had several articles published and has presented numerous papers on national and international conferences. She also has served as a manuscript reviewer for the professional journal, *The Journal of Educational and Psychological Measurement*, and for the American Educational Research Association (AERA). Additionally, she is a member of numerous professional affiliations. Jianxia currently is an assistant professor at Mississippi State University.