Computer Use and Its Relation to Academic Achievement in Mathematics, Reading, and Writing

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Table of Contents

Computer Use and its Relation to Academic Achievement in Mathematics, Reading, and Writing

In commerce and manufacturing, multinational corporations, and individual households, computer technology has fundamentally altered how business is conducted and how people communicate. In the field of education, computers have become a common fixture in this country's schools. In 1980, less than 20 percent of elementary, junior, and senior high schools in the U.S. were equipped with microcomputers. Less than a decade later, virtually all public schools had some computing capability (U.S. Bureau of the Census, 1989). Similarly, student access to computers has increased dramatically, from more than 60 students per computer in 1984 to approximately six students per computer in 1998 (U.S. Bureau of the Census, 1998). The important question for educators and policymakers then becomes: do computers enhance student learning?

The results from a number of published studies on the relationship between computer use and academic achievement indicate that this technology can bolster student outcomes (Becker, 1994; Christmann and Badgett, 1999; Hativa, 1994; Kozma, 1991; Kulik and Kulik, 1987; Liao, 1992; Niemiec and Walberg, 1987; Niemiec and Walberg, 1992; Ryan, 1991; Van Dusen and Worthen, 1994). In their research synthesis on computer-based instruction (CBI), for example, Niemiec and Walberg (1992) calculated a positive average CBI effect on achievement of 0.42 standard deviations. Ryan (1991) computed a mean effect size of 0.31 in a meta-analysis of 40 published and unpublished studies on computer use and achievement in elementary schools. Most of the subject-specific research on computer use and achievement have examined performance in science and mathematics. In studies that focused on mathematics achievement, results have generally pointed to significant positive effects for computer use (Clariana and Schultz, 1988; Mayes, 1992; Mevarich, 1994; Moore, 1988; Rhoads, 1986; Van Dusen and Worthen, 1994). In their meta-analysis of studies on computer-assisted instruction (CAI), Christmann, Badgett, and Lucking (1997) estimated effect sizes for eight curricular areas. The authors calculated an overall mean effect size of 0.209 and mean effect sizes of 0.179 for mathematics achievement, and 0.262 for reading achievement. For English achievement, however, they found a negative (–0.420) effect size.

There is some evidence that the access to computers and the academic benefits that can be derived from computer use are not the same for all students. Although monies from federally-funded programs such as Title I that are targeted to assist disadvantaged students are often used to purchase computers (Scott, Cole and Engel, 1992), high-income and white students tend to have greater access than low-income and Black students, and non-English speaking students tend to have the least access (Cuban, 1993; Neuman, 1991; Sutton, 1991). Moreover, even when high-socioeconomic status (SES) schools and low-SES schools have comparable student-to-computer ratios, students in low-SES schools are likelier to use computers for drill and practice exercises while their more affluent counterparts engage in more challenging activities (Cole and Griffin, 1987; Kozma and Croninger, 1992; Watt, 1982). A number of quasi-experimental studies of the computer-achievement relationship for students of different abilities have also been conducted. The results from these designs are mixed. Some studies show that even under the same treatment conditions, high-ability students receive greater benefits from learning by computer than their lower-ability classmates (Hativa, 1994; Hativa and Becker, 1994; Hativa and Shorer, 1989; Munger and Loyd, 1989; Osin, Nesher and Ram, 1994) while other studies indicate that high- and low-ability students attain similar gains (Becker, 1992; Clariana and Schultz, 1988). However, the results from longitudinal studies of computer-assisted instruction have prompted some researchers to conclude that computerized learning contributes to the increasing achievement gaps between high- and low-SES students and between high- and low-ability students (Hativa, 1994; Hativa and Becker, 1994; Hativa and Shorer, 1989). Finally, gender differences in achievement attained using computer-based instruction have been reported in some studies. Clariana and Schultz (1993) found that low-achieving eighth-grade females attained significantly smaller gains in mathematics, compared with high- and low-ability males and high-ability females, whereas in language arts, the low-ability females made the largest gains relative to the other three student groups. When ability is not taken into account, though, achievement gains for males tend to be significantly higher than the gains attained by their female classmates (Hativa and Shorer, 1989; Neuman, 1991).

Perhaps the most striking feature in the literature on computer use and achievement is the central role teachers play in implementing computer use in the classroom (Clariana and Schultz, 1993; Hativa, 1994; Hativa and Becker, 1994; Moore, 1988; Van Dusen and Worthen, 1994). Considerable evidence indicates that even though teachers have had increasing access to computers for instruction, very few actually use them. In 1996, for example, the National Education Association reported that although 84 percent of all public school teachers said personal computers were available to them, only around 60 percent indicated that they ever used them (U.S. Census Bureau, 1998). Analysis of teacher data from the National Education Longitudinal Study (NELS) showed that about half of the eighth-grade mathematics teachers reported that their students spent less than 10 percent of class time working on computers (Owens and Waxman, 1994), while across subject matter, teachers averaged only about 4 percent of all instructional time using computers (Cuban, 1993). A survey of middle school mathematics and science teachers in South Carolina also showed that although 70 percent of these teachers had access to computers, almost half of those with access did not use them (Dickey and Kherlopian, 1987). Moreover, these data may be optimistic since self-reports by teachers regarding computer use may be unreliable and exhibit an upward bias (Huang and Waxman, 1996).

Even though computer technology may be widely available, in general it is poorly integrated into the classroom curriculum and is under-used (Maddux, Johnson, and Harlow, 1993; Becker, 1991; Ognibene and Stiele, 1990). In order to maximize the benefits that can be derived from new technology in the classroom, teachers need training for proficiency in the technology; they also need to be trained to change their teaching methods in order to take full advantage of the new technology (Bright and Prohosch, 1995). Ryan's (1991) meta-analysis showed that teacher training in computers is significantly related to the academic achievement of treatment groups, but the effect size for instructors with less than 10 hours of training was smaller than the effect size for teachers with no computer training at all. Further, Sheingold and Hadly (1990) estimated that it takes at least five years for experienced teachers to feel comfortable using computers in non-routine ways.

Evidence suggests that more fully integrating computers into the classroom is more likely to occur at the elementary rather than the secondary level, as a result of more basic subject matter, a focus on skills versus content, and because of the teachers themselves (Sutton, 1991; Cuban, 1993). In elementary school, the focus tends to be on mastering basic skills, while in high school, students often apply complex concepts. Elementary school teachers are broadly trained and usually spend all day with one group, while secondary school teachers are subject matter specialists who see students for one class period per day.

Most of the research on technology in schools indicates that computers have had little effect on teaching practices or classroom activities. Some authors (Cuban, 1993; Scott, Cole, and Engel, 1992) have argued that computer use in schools simply follows the pattern of other new technology when it was introduced (e.g., radio and television). According to this view, the educational system’s conservatism resists innovation, seeking to retain current goals and social organization. As a result, new technology is incorporated in “old” ways. Moreover, the sharp increase in the number of computers in schools is primarily due to the efforts of those who profit from this expansion, such as hardware and software makers, not educators. These profiteers have been particularly successful by supplying goods and services for federally-funded programs for low-achieving minority students. Such programs often feature computer systems with “drill and kill” software which, according to some observers, are designed to replace teachers and control student behavior (Scott, Cole, and Engel, 1992).

A recent study of the relation between computer use and mathematics achievement was carried out by Wenglinsky (1998). After adjusting for indicators of SES and applying data from the 1996 National Assessment of Educational Progress (NAEP), he found that computer usage was negatively related to mathematics achievement in grades 4 and 8. He also found that the type of computer use was related to achievement, with teacher-reported computer use for higher-order skills being more positively related to achievement than teacher-reported computer use for lower-order skills. However, several things about this study are problematic. One major problem is that both computer use and achievement are also related to race/ethnicity. The confounding effects of race and ethnicity could have led to apparent negative relations between computer use and achievement. A second problem is that Wenglinsky did not make use of what may be the best available SES variable now available in NAEP: free- or reduced-price lunch eligibility. Consequently, the effects he found may still be confounded by social class. Third, he did not examine teacher-reported (as opposed to student-reported) frequency of computer use, which might be a more valid indicator of instructional strategy. Finally, he did not examine possible differential effects of computer use for demographic subgroups or for teachers who were better prepared to use computers.

The Present Study

The purpose of this study is to examine patterns of computer use in U.S. schools and the relation of computer use to academic achievement in mathematics, reading and writing. In this report, we first discuss methodological issues. We then present the results of analyses of the social distribution of computer use. Next, we turn to the relation of computer use to achievement. Finally, we present recommendations for future research and possible changes in NAEP.

This research is based on evidence from NAEP. We make use of the 1996 main assessment in mathematics and the 1998 main assessments in reading and writing. NAEP is the most extensive and valid source of data on what fourth-, eighth-, and twelfth-grade students in the United States know and are able to do. Therefore, NAEP is well suited to describing the patterns of achievement in the U.S.

Measurement of Computer Use in NAEP

This section describes analyses of the computer use data collected in the 1996 main assessment in mathematics and the1998 NAEP main assessments in reading and writing achievement. The section also gives a brief description of how each of the variables in the achievement model is measured in the analyses that follow. The (often considerable) weaknesses in the measurement of variables used, and measurement alternatives considered, are described.

Measurement of Computer Use in the 1996 NAEP Mathematics Assessment

The data on frequency of computer use in the 1996 NAEP mathematics assessment come from three items (the exact text of these items is given in Appendix A). Two are student self-reports of frequency of computer use at home and at school. The third (available only at grades 4 and 8) is a report by the teacher on the frequency of classroom computer use, and is, therefore, not specifically a report about any particular child's computer use. One might argue that the teacher report is more reliable and expresses the intent of the instructional strategy being used in the classroom. On the other hand, teacher reports about the entire classroom fail to reflect any between-student variations within classes, but capture variations among classes. The student report, while it may be more specific, is not necessarily reliable or a reflection of the instructional intent. The student report may reflect the student's own volition or the salience of computer use for that student.

One other item related to computer use in mathematics instruction can be obtained from the teacher questionnaire (available only at grades 4 and 8). This question asks about teachers' primary use of computers for mathematics instruction. The possible responses are:

- "Drill and practice"
- "Demonstration of new topics in mathematics"

- “Playing mathematical/learning games”

- “Simulations and applications”

Considering the adequacy of the various available measures, it is difficult to know how students interpreted questions about computer use. For example, how clearly did students differentiate calculators from computers? There are several reasons to be concerned about the validity of student-reported data on computer use. The first is that the teacher and student reports are correlated rather poorly. Tables 1 and 2 show the relation between teacher responses and student responses about frequency of computer use at school. As these tables demonstrate, the correlation between the two variables is low (γ[1] = 0.16, τ[2] = 0.10 at grade 4 and $\gamma = 0.23$ or $\tau = 0.13$ at grade 8). While this low correlation is not impossible if both variables are valid, the low correlation does raise the question of which indicator to take more seriously.

Table 1a. Percent Agreement Between Teacher Reported Computer Use for Mathematics Instruction and Student Reported Computer Use for Mathematics (Grade 4)

		Percentage of Student Reported Computer Use			
Percentage of Teacher Reported Computer Use		Never/Hardly Ever	Once or Twice a Month	Once or Twice a Week	Every Day
Never/Hardly Ever	21.6	62.9	9.9	17.1	10.1
Once or Twice a Month	19.3	59.0	12.1	17.4	11.5
Once or Twice a Week	46.3	54.2	10.8	22.4	12.6
Every Day Use	12.8	46.9	7.3	20.1	25.7

Table 1b. Percent Agreement Between Student Reported Computer Use for Mathematics and Teacher Reported Computer Use for Mathematics Instruction (Grade 4)

		Percentage of Teacher Reported Computer Use			
Percentage of Student Reported Computer Use		Never/Hardly Ever	Once or Twice a Month	Once or Twice a Week	Every Day
Never/Hardly Ever	56.1	24.2	20.3	44.8	10.7
Once or Twice a Month	10.4	20.5	22.5	48.0	9.0
Once or Twice a Week	20.0	18.4	16.9	51.9	12.8
Every Day Use	13.5	16.2	16.4	43.0	24.3

[1] Goodman and Kruskal’s gamma (see Goodman and Kruskal, 1954)
[2] Kendall’s tau (see Kendall, 1938)

Table 2a. Percent Agreement Between Teacher Reported Computer Use for Mathematics Instruction and Student Reported Computer Use for Mathematics (Grade 8)

Percentage of Teacher Reported Computer Use		Percentage of Student Reported Computer Use: Never/Hardly Ever	Once or Twice a Month	Once or Twice a Week	Every Day
Never/Hardly Ever	69.3	62.2	12.3	12.6	12.9
Once or Twice a Month	20.4	45.8	24.9	16.8	12.5
Once or Twice a Week	8.8	41.4	15.2	31.8	11.6
Every Day Use	1.6	43.4	13.1	10.2	33.3

Table 2b. Percent Agreement Between Student Reported Computer Use for Mathematics and Teacher Reported Computer Use for Mathematics Instruction (Grade 8)

Percentage of Student Reported Computer Use		Percentage of Teacher Reported Computer Use: Never/Hardly Ever	Once or Twice a Month	Once or Twice a Week	Every Day
Never/Hardly Ever	56.8	76.0	16.4	6.4	1.2
Once or Twice a Month	15.1	56.3	33.5	8.8	1.3
Once or Twice a Week	15.1	57.9	22.6	18.5	1.1
Every Day Use	13.0	68.0	19.6	6.8	4.0

Examining the detailed responses raises further questions. Note that, in classrooms where teachers report never or hardly ever using computers, 27.2 percent of the fourth-grade students claim to use computers at least once a week. Similarly, in mathematics classes where teachers report never or hardly ever using computers, 25.5 percent of the grade 8 students claim to use computers at least once a week. Again, while these reports are not mathematically impossible if both teacher and student reports are valid, they do seem improbable.

Comparing the absolute level of computer use in school, as reported by teachers and students, also raises questions about the validity of these variables. At grade 8, 69.3 percent of the teachers surveyed say that they never or hardly ever use computers in their class, but 43.2 percent of students say they use computers once a month or more. The discrepancy at grade 4 seems easier to understand—21.6 percent of teachers say they never or rarely use computers, while 56.1 percent of students say they never or rarely use computers. This is sensible if teachers assign only selected students to use computers. Such an interpretation is further supported by the fact that 59.1 percent of fourth-grade teachers say they use computers at least once a week, but only 33.5 percent of students say they use computers at least once a week in school.

It is important to know *how* computer technology is used in the classroom when studying mathematics achievement. The data on type of computer usage related to mathematics instruction is very limited. The only specific item is the teachers' report of primary use of computers for mathematics instruction. As mentioned above, the responses are: *drill and practice, demonstration of new topics, playing mathematical/learning games,* or *simulations and applications*.

The question about the physical availability of computers is straightforward. Teachers were asked if there were computers in the classroom—and if so, how many, and if not, whether computers were readily available in a nearby lab. This question provides a reasonably clear picture of the physical access to computers, but it does not provide any information about available software, hardware capabilities, or technical support, and therefore, the actual (as opposed to theoretical) availability of computers for instruction.

Measurement of Computer Use in the 1998 NAEP Reading Assessment

The data on computer use in the 1998 NAEP reading assessment come from six items (the exact text of these items in given in Appendix B). Two are student self-reports of frequency of computer use for schoolwork and computer use in a school or public library. These items differ from those in the 1996 assessment in mathematics in their lack of specificity. The self-report of frequency of computer use for schoolwork does not clearly differentiate between use of the computer at home versus at school. Hence, it is difficult to know if students are responding about use of computers for schoolwork at home, at school, or both. Moreover, the student report of frequency of computer use for schoolwork does not specify whether computer use is related to reading. Therefore, we do not know if the computer use reported is in any way related to schoolwork involving reading (for example it could involve drill in computation or other mathematics items with a low reading load).

We considered the self-report of computer use in school or public libraries to be irrelevant to this study, since it is unclear if the computer use was for reading-related schoolwork, or even for anything related to schoolwork at all. The use of computers in libraries could have been for electronic mail, games, or non-academic Internet access. In fact, students could even be reporting the use of on-line library catalogues as computer use.

Four other items related to computer use can be obtained from the teacher questionnaire (available only at grades 4 and 8). One question asks the teacher about the frequency of use of "computer software for reading instruction." Three other questions ask the teacher about the frequency with which students are asked to use a computer to:

- "Read stories or do work related to reading instruction"
- "Do spelling, punctuation, or grammar exercises"
- "Write drafts or final versions of stories or reports"

We judged that the first question, about frequency with which students are asked to "Read stories or do work related to reading instruction," is most relevant to reading instruction, since the latter two questions seem to involve writing more than reading.

Note that, as in the case of the 1996 NAEP mathematics achievement data, teacher reports are about computer use in students' classrooms, and ,therefore, are not specifically reports about any particular student's computer use. On the other hand, the student reports are vague regarding where computer use occurs and whether it is explicitly related to reading.

As with mathematics, the teacher and student reports of computer use are not well correlated. Table 3 shows the relation, at grade 4, between teacher responses on the use of computer software for reading instruction and student responses on using the computer for schoolwork. Table 4 shows the relation between teacher responses on using computers for reading stories and student responses on using the computer for schoolwork, also at grade 4. Tables 5 and 6 show the corresponding relations at grade 8. As these tables demonstrate, the correlation between the two variables is low ($\gamma = 0.07$ and $\gamma = 0.10$, $\tau = 0.06$ and $\tau = 0.04$ at grade 4, and $\gamma = -0.04$ and $\gamma = 0.05$, $\tau = -0.02$ and $\tau = 0.04$ at grade 8). As in Tables 1 and 2, while this low a correlation is not impossible if both variables are valid, the low correlation does raise the question of whether they are measuring the same thing and, if so, which one to take more seriously.

Table 3a. Percent Agreement Between Student Reported Computer Use for Schoolwork and Teacher Reported Software Use for Reading Instruction (Grade 4)

		Percentage of Teacher Reported Software Use			
Percentage of Student Reported Computer Use		Never/Hardly Ever	Once or Twice a Month	Once or Twice a Week	Every Day
Never/Hardly Ever	53.9	59.9	16.7	15.4	8.0
Once or Twice a Month	17.9	60.8	19.6	13.0	6.5
Once or Twice a Week	19.8	54.7	19.5	17.4	8.3
Every Day Use	8.4	53.0	11.6	20.9	14.5

Table 3b. Percent Agreement Between Teacher Reported Software Use for Reading Instruction and Student Reported Computer Use for Schoolwork (Grade 4)

		Percentage of Student Reported Computer Use			
Percentage of Teacher Reported Software Use		Never/Hardly Ever	Once or Twice a Month	Once or Twice a Week	Every Day
Never/Hardly Ever	58.4	55.2	18.7	18.5	7.7
Once or Twice a Month	17.4	51.8	20.3	22.2	5.7
Once or Twice a Week	15.9	52.4	14.8	21.7	11.1
Every Day Use	8.3	51.7	13.9	19.7	14.7

Table 4a. Percent Agreement Between Student Reported Computer Use for Schoolwork and Teacher Reported Computer Use for Reading Stories or Doing Work Related to Reading Instruction (Grade 4)

		Percentage of Teacher Reported Computer Use			
Percentage of Student Reported Computer Use		Never/Hardly Ever	Once or Twice a Month	Once or Twice a Week	Every Day
Never/Hardly Ever	53.8	52.4	15.1	18.6	14.0
Once or Twice a Month	17.9	52.9	16.4	17.4	13.3
Once or Twice a Week	19.9	45.0	18.4	20.3	16.2
Every Day Use	8.5	41.0	9.8	28.8	20.4

Table 4b. Percent Agreement Between Teacher Reported Computer Use for Reading Stories or Doing Work Related to Reading Instruction and Student Reported Computer Use for Schoolwork (Grade 4)

		Percentage of Student Reported Computer Use			
Percentage of Teacher Reported Computer Use		Never/Hardly Ever	Once or Twice a Month	Once or Twice a Week	Every Day
Never/Hardly Ever	50.0	56.2	18.9	17.9	7.0
Once or Twice a Month	15.5	52.2	18.9	23.5	5.4
Once or Twice a Week	19.6	51.0	15.9	20.6	12.5
Every Day Use	14.8	50.5	16.0	21.7	11.7

Table 5a. Percent Agreement Between Student Reported Computer Use for Schoolwork and Teacher Reported Software Use for Reading Instruction (Grade 8)

		Percentage of Teacher Reported Software Use			
Percentage of Student Reported Computer Use		Never/Hardly Ever	Once or Twice a Month	Once or Twice a Week	Every Day
Never/Hardly Ever	32.9	77.2	14.7	4.8	3.4
Once or Twice a Month	28.6	78.8	15.5	3.7	2.0
Once or Twice a Week	23.8	80.5	12.8	4.8	1.9
Every Day Use	14.7	78.2	13.5	4.2	4.1

Table 5b. Percent Agreement Between Teacher Reported Software Use for Reading Instruction and Student Reported Computer Use for Schoolwork (Grade 8)

		Percentage of Student Reported Computer Use			
Percentage of Teacher Reported Software Use		Never/Hardly Ever	Once or Twice a Month	Once or Twice a Week	Every Day
Never/Hardly Ever	78.6	32.3	28.7	24.4	14.6
Once or Twice a Month	14.3	33.9	31.0	21.3	13.9
Once or Twice a Week	4.4	35.5	24.3	26.1	14.1
Every Day Use	2.7	40.6	20.8	16.3	22.3

Table 6a. Percent Agreement Between Student Reported Computer Use for Schoolwork and Teacher Reported Computer Use for Reading Stories or Doing Work Related to Reading Instruction (Grade 8)

		Percentage of Teacher Reported Computer Use			
Percentage of Student Reported Computer Use		Never/Hardly Ever	Once or Twice a Month	Once or Twice a Week	Every Day
Never/Hardly Ever	32.8	61.6	14.0	14.0	10.4
Once or Twice a Month	28.6	62.5	12.9	12.8	11.8
Once or Twice a Week	23.9	58.5	13.9	17.3	10.3
Every Day Use	14.8	56.0	14.0	16.3	13.3

Table 6b. Percent Agreement Between Teacher Reported Computer Use for Reading Stories or Doing Work Related to Reading Instruction and Student Reported Computer Use for Schoolwork (Grade 8)

		Percentage of Student Reported Computer Use			
Percentage of Teacher Reported Computer Use		Never/Hardly Ever	Once or Twice a Month	Once or Twice a Week	Every Day
Never/Hardly Ever	60.3	33.5	29.6	23.2	13.7
Once or Twice a Month	13.7	33.4	26.9	24.1	15.5
Once or Twice a Week	14.8	30.9	24.8	27.9	16.3
Every Day Use	30.5	30.0	22.0	17.5	11.2

Examining the detailed responses raises further questions. Note that where teachers report never or hardly ever using computer software for reading instruction, 26.2 percent of the grade 4 students in language arts report using computers at least once a week for schoolwork. Moreover, 23.4 percent of the grade 4 students who report never or hardly ever using the computer for schoolwork have teachers who report using computer software for reading instruction at least once a week. Similarly, where teachers report never or hardly ever using computer software for reading instruction, 39.0 percent of the eighth-grade students in language arts report using computers at least once a week for schoolwork, and 8.2 percent of the students who report never or hardly ever using the computer for schoolwork have teachers who report using computer software for reading instruction at least once a week.

Tables 7 and 8 show the relations between the two teacher-reported computer use variables (use of computer software for reading instruction and computer use for reading stories or work related to reading instruction) at grades 4 and 8, respectively. The two teacher reports have a much stronger relation ($\gamma = 0.68$ or $\tau = 0.51$ at grade 4 and $\gamma = 0.47$ or $\tau = 0.26$ at grade 8). This is to be expected since both are teacher reports and, hence, share a common method. Yet, discrepancies appear even in these data, with 3.2 percent of fourth-grade teachers (and 2.3 percent of eighth-grade teachers) who report never or hardly ever using the computer for reading stories or for doing work related to reading instruction reporting the use of computer software for reading instruction at least once a week.

Table 7a. Percent Agreement Between Teacher Reported Computer Use for Reading Stories or Doing Work Related to Reading Instruction and Teacher Reported Software Use for Reading Instruction (Grade 4)

		Percentage of Teacher Reported Software Use			
Percentage of Teacher Reported Computer Use		Never/Hardly Ever	Once or Twice a Month	Once or Twice a Week	Every Day
Never/Hardly Ever	50.1	84.1	12.7	3.0	0.2
Once or Twice a Month	15.5	37.7	41.5	15.3	5.5
Once or Twice a Week	19.6	27.2	9.8	48.1	14.9
Every Day Use	14.8	32.7	18.6	18.0	30.6

Table 7b. Percent Agreement Between Teacher Reported Software Use for Reading Instruction and Teacher Reported Computer Use for Reading Stories or Doing Work Related to Reading Instruction (Grade 4)

		Percentage of Teacher Reported Computer Use			
Percentage of Teacher Reported Software Use		Never/Hardly Ever	Once or Twice a Month	Once or Twice a Week	Every Day
Never/Hardly Ever	58.2	72.5	10.0	9.2	8.3
Once or Twice a Month	17.4	36.4	36.9	11.0	15.7
Once or Twice a Week	16.0	9.5	14.8	59.1	16.6
Every Day Use	8.4	1.4	10.1	34.8	53.7

Table 8a. Percent Agreement Between Teacher Reported Computer Use for Reading Stories or Doing Work Related to Reading Instruction and Teacher Reported Software Use for Reading Instruction (Grade 8)

		Percentage of Teacher Reported Software Use			
Percentage of Teacher Reported Computer Use		Never/Hardly Ever	Once or Twice a Month	Once or Twice a Week	Every Day
Never/Hardly Ever	59.3	89.0	8.7	1.9	0.4
Once or Twice a Month	13.7	50.9	41.2	4.1	3.8
Once or Twice a Week	15.2	70.6	12.8	13.7	2.9
Every Day Use	11.8	67.2	13.7	4.9	14.1

Table 8b. Percent Agreement Between Teacher Reported Software Use for Reading Instruction and Teacher Reported Computer Use for Reading Stories or Doing Work Related to Reading Instruction (Grade 8)

		Percentage of Teacher Reported Computer Use			
Percentage of Teacher Reported Software Use		Never/Hardly Ever	Once or Twice a Month	Once or Twice a Week	Every Day
Never/Hardly Ever	78.4	67.3	8.9	13.7	10.2
Once or Twice a Month	14.4	36.1	39.1	13.5	11.3
Once or Twice a Week	4.3	25.4	13.0	48.0	13.5
Every Day Use	2.9	7.5	18.1	15.7	58.7

As when studying mathematics achievement, it is important to know how computer technology is used in the classroom. The data on computer usage related to reading instruction in NAEP is meager. The only specific item is teacher-reported frequency of computer use to "Read stories or do work related to reading instruction." We found it difficult to classify this item in terms of higher- versus lower-order cognitive skills, or any other instructionally meaningful taxonomy.

The question about the physical availability of computers is similar to the question used in the 1996 assessment in mathematics, except that there is no reference to a specific subject area (e.g., reading) in the question stem and the response options are slightly different. Nevertheless, compared to the data on the frequency of computer use, the data on computer access in the 1998 reading assessment are somewhat less ambiguous (although still quite limited).

Measurement of Computer Use in the 1998 NAEP Writing Assessment

The data on computer use in the 1998 NAEP writing assessment come from seven items (the exact text of these items is given in Appendix C). Three of the items ask students to report on frequency of using computers to carry out the following tasks for classes:

- "Do spelling, punctuation, or grammar exercises"
- "Write in a log or journal"
- "Write drafts or final versions of stories or reports"

These items are more specific with regard to activity compared to the student questions in the 1998 assessment in reading, but lack specificity regarding the *location* of use. That is, the self-report of computer use for classwork does not clearly differentiate between use of the computer at home versus at school. Hence, it is difficult to know if students are responding to using computers for classwork at home, at school, or both. Moreover, we do not know if the computer use reported is related to schoolwork intended to teach *writing.* (For example, writing in a journal could involve keeping a factual log of temperatures for a science class.) A fourth item on the student questionnaire is about use of computers at home for schoolwork and is identical to a question used in the 1996 assessment in mathematics.

Two other items related to computer use in writing instruction can be obtained from the teacher questionnaire (available only at grades 4 and 8). These questions ask the teacher about the frequency with which students are asked to use a computer to:

- "Do spelling, punctuation, or grammar exercises"
- "Write drafts or final versions of stories or reports"

We judged that a third question, about frequency with which students are asked to use a computer to "Read stories or do work related to reading instruction," was not relevant to the writing assessment.

Note that, as in the case of the 1996 NAEP mathematics and 1998 NAEP reading assessments, teacher reports focus on computer use in students' classrooms, and therefore, are not specifically reports about any particular student's computer use. On the other hand, the student reports are vague regarding where computer use occurred, and whether it is explicitly related to writing instruction.

Also, as with mathematics and reading, the teacher and student reports are correlated rather poorly. Table 9 shows the relation between teacher and student responses about the frequency of computer use for doing spelling, punctuation, and grammar exercises at grade 4. Table 10 shows the relation between teacher and student reports of the frequency of use of computers for writing drafts or final versions of stories or reports at grade 4. Tables 11 and 12 show the relation between these same questions at grade 8. As these tables demonstrate, the correlation between the two variables is low ($\gamma = 0.09$ and $\gamma = 0.15$, $\tau = 0.06$ and $\tau = 0.10$ at grade 4, and $\gamma = 0.09$ and $\gamma = 0.15$, $\tau = 0.06$ and $\tau = 0.10$ at grade 8), and the same concerns apply as in the previous subject areas.

Table 9a. Percent Agreement Between Teacher Reported Computer Use for Doing Spelling, Punctuation, and Grammar Exercises, and Student Reported Computer Use for Doing Spelling, Punctuation, and Grammar Exercises (Grade 4)

		Percentage of Student Reported Computer Use			
Percentage of Teacher Reported Computer Use		Never/Hardly Ever	Once or Twice a Month	Once or Twice a Week	Every Day
Never/Hardly Ever	52.7	38.8	11.3	24.2	25.6
Once or Twice a Month	19.9	36.9	13.1	26.7	23.3
Once or Twice a Week	19.0	28.7	11.9	29.4	30.1
Every Day Use	8.5	28.6	12.0	28.5	30.9

Table 9b. Percent Agreement Between Student Reported Computer Use for Doing Spelling, Punctuation, and Grammar Exercises, and Teacher Reported Computer Use for Doing Spelling, Punctuation, and Grammar Exercises (Grade 4)

		Percentage of Teacher Reported Computer Use			
Percentage of Student Reported Computer Use		Never/Hardly Ever	Once or Twice a Month	Once or Twice a Week	Every Day
Never/Hardly Ever	35.6	57.4	20.6	15.2	6.8
Once or Twice a Month	11.8	50.4	22.0	19.0	8.6
Once or Twice a Week	26.1	49.0	20.4	21.4	9.2
Every Day Use	26.5	51.0	17.5	21.6	9.9

Table 10a. Percent Agreement Between Teacher Reported Computer Use for Writing Drafts or Final Versions of Stories or Reports, and Student Reported Computer Use for Writing Drafts or Final Versions of Stories or Reports (Grade 4)

		Percentage of Student Reported Computer Use			
Percentage of Teacher Reported Computer Use		Never/Hardly Ever	Once or Twice a Month	Once or Twice a Week	Every Day
Never/Hardly Ever	42.0	34.5	32.4	20.7	12.5
Once or Twice a Month	39.1	24.8	39.5	23.9	11.8
Once or Twice a Week	16.3	22.4	32.8	28.6	16.3
Every Day Use	2.6	12.0	37.6	31.9	18.5

Table 10b. Percent Agreement Between Student Reported Computer Use for Writing Drafts or Final Versions of Stories or Reports, and Teacher Reported Computer Use for Writing Drafts or Final Version of Stories or Reports (Grade 4)

		Percentage of Teacher Reported Computer Use			
Percentage of Student Reported Computer Use		Never/Hardly Ever	Once or Twice a Month	Once or Twice a Week	Every Day
Never/Hardly Ever	28.1	51.4	34.5	13.0	1.1
Once or Twice a Month	35.4	38.4	43.7	15.1	2.8
Once or Twice a Week	23.5	36.8	39.8	19.8	3.5
Every Day Use	13.0	40.4	35.4	20.5	3.7

Table 11a. Percent Agreement Between Teacher Reported Computer Use for Doing Spelling, Punctuation, and Grammar Exercises, and Student Reported Computer Use for Doing Spelling, Punctuation, and Grammar Exercises (Grade 8)

		Percentage of Student Reported Computer Use			
Percentage of Teacher Reported Computer Use		Never/Hardly Ever	Once or Twice a Month	Once or Twice a Week	Every Day
Never/Hardly Ever	68.4	49.8	17.2	18.7	14.3
Once or Twice a Month	14.0	41.0	20.6	22.7	15.7
Once or Twice a Week	11.0	41.8	17.1	25.0	16.0
Every Day Use	6.6	46.2	17.4	18.9	17.5

Table 11b. Percent Agreement Between Student Reported Computer Use for Doing Spelling, Punctuation, and Grammar Exercises, and Teacher Reported Computer Use for Doing Spelling, Punctuation, and Grammar Exercises (Grade 4)

		Percentage of Teacher Reported Computer Use			
Percentage of Student Reported Computer Use		Never/Hardly Ever	Once or Twice a Month	Once or Twice a Week	Every Day
Never/Hardly Ever	47.4	71.8	12.1	9.7	6.5
Once or Twice a Month	17.7	66.6	16.2	10.7	6.5
Once or Twice a Week	20.0	64.0	15.9	13.8	6.3
Every Day Use	14.9	65.7	14.7	11.8	7.8

Table 12a. Percent Agreement Between Teacher Reported Computer Use for Writing Drafts or Final Versions of Stories or Reports, and Student Reported Computer Use for Writing Drafts or Final Versions of Stories or Reports (Grade 8)

		Percentage of Student Reported Computer Use			
Percentage of Teacher Reported Computer Use		Never/Hardly Ever	Once or Twice a Month	Once or Twice a Week	Every Day
Never/Hardly Ever	35.4	33.7	35.3	20.6	10.4
Once or Twice a Month	46.3	22.8	43.1	23.0	11.1
Once or Twice a Week	15.3	21.1	37.3	27.4	14.2
Every Day Use	3.0	18.2	33.5	29.3	19.0

Table 12b. Percent Agreement Between Student Reported Computer Use for Writing Drafts or Final Versions of Stories or Reports, and Teacher Reported Computer Use for Writing Drafts, or Final Version of Stories or Reports (Grade 4)

		Percentage of Teacher Reported Computer Use			
Percentage of Student Reported Computer Use		Never/Hardly Ever	Once or Twice a Month	Once or Twice a Week	Every Day
Never/Hardly Ever	26.3	45.4	40.2	12.3	2.1
Once or Twice a Month	39.2	31.8	51.0	14.5	2.6
Once or Twice a Week	23.0	31.7	46.2	18.2	3.9
Every Day Use	11.6	31.7	44.5	18.8	5.0

Examining the detailed responses raises further questions. Note that 49.8 percent of the fourth-grade students whose language arts teachers report *never or hardly ever* asking their students to use a computer for doing spelling, punctuation, and grammar exercises report that they use computers *at least once a week* for doing spelling, punctuation, and grammar exercises. Moreover, 28.6 percent of the fourth-grade students whose language arts teachers report asking their students to use a computer for doing spelling, punctuation, and grammar exercises *every day* report *never or hardly ever* using the computer for doing spelling, punctuation, and grammar exercises. The discrepancies at grade 8 are not so obvious, but 33.0 percent of the eighth-grade students whose language arts teachers report *never or hardly ever* asking their students to use a computer for doing spelling, punctuation, and grammar exercises report that they use computers *at least once a week* for doing spelling, punctuation, and grammar exercises. Moreover, 46.2 percent of the eighth-grade students whose language arts teachers report asking their students to use a computer for doing spelling, punctuation, and grammar exercises *every day* report *never or hardly ever* using the computer for doing spelling, punctuation, and grammar exercises.

Student and teacher reports of the frequency of computer use for writing drafts or final versions of stories or reports are in closer agreement than the corresponding reports for the previous computer use variable. However, it is still true that 33.2 percent of the grade 4 students whose language arts teachers report *never or hardly ever* asking their students to use a computer for writing drafts or final versions of stories or reports indicate that they use computers *at least once a week* for these activities. Moreover, 12.0 percent of the grade 4 students whose language arts teachers report asking their students to use a computer for writing drafts or final versions of stories or reports *every day* report *never or hardly ever* using the computer for these activities. Note, however, that *every day* use of the computer for this purpose was understandably quite rare (with only 2.6 percent of teachers so reporting). The discrepancies at the eighth grade were comparatively less extreme, but 31.0 percent of the grade 8 students whose language arts teachers report *never or hardly ever* asking their students to use a computer for writing drafts or final versions of stories or reports indicate that they use computers *at least once a week* this purpose. Furthermore, 18.2 percent of the grade 8 students whose language arts teachers report asking their students to use a computer for writing drafts or final versions of stories or reports *every day* report *never or hardly ever* using the computer for these activities.

With regard to knowing *how* computer technology is used in the classroom, the data on computer usage related to writing instruction in NAEP is better than that for reading. In some ways it is also better than that for mathematics, but in other ways, it is still very limited. It seems clear that the use of computers to do spelling, punctuation, or grammar exercises is rather low in cognitive level and unrelated to production tasks in writing. It would also seem that the task of using the computer to write drafts or final versions of reports or stories is higher in cognitive level and much more related to writing production tasks. The third type of computer use—the use of computers to write logs or journals (available as a student report only)—is less clear. While this may indicate a writing production task similar to writing stories or reports, it may involve writing logs that require little actual written composition.

As in the mathematics and reading assessments, the data on access to computers are somewhat less ambiguous, but still quite limited.

The Social Distribution of Computer Use

In this section we briefly review findings about differences among students from different economic, gender, and racial/ethnic groups with regard to the availability and use of computers for schoolwork.

Use of a Computer at Home for Schoolwork

Student-reported home computer use presents some seemingly contradictory patterns that stem from the complexity of this variable. On the one hand, *possession* of a computer at home is an indicator of SES and can be expected to behave like such an indicator. (In fact, it is one of the items used to measure SES in other surveys, such as NELS: 88.) On the other hand, the patterns of computer usage among those who have computers reveal differences among families in how this resource is used to promote academic achievement. The computer use question asked of the students in the 1998 assessment in writing, like that of the 1996 assessment in mathematics, but unlike the 1998 assessment in reading, asks specifically about computer use for schoolwork *at home* versus *at school*, making interpretation more straightforward than in the 1998 assessment in reading, where the question did not differentiate between use at home or at school.

Table 13 gives the relation between student-reported computer use at home for schoolwork and free- or reduced-price lunch eligibility, gender, and race/ethnicity for fourth-grade students based on the 1996 assessment in mathematics and 1998 assessment in writing. The data show that there has been a substantial overall decline in the proportion of fourth-grade students who had no computer at home (from 42 percent nationally to 30.5 percent).

Table 13. Student Reported Home Computer Use for Schoolwork in 1996 and 1998 by SES, Gender, and Race/Ethnicity (Grade 4)

	Grade 4 Home Computer Use (%)				
	No Computer at Home	Never or Hardly Ever	Once or Twice a Month	Once or Twice a Week	Every Day
U.S. Population 1996	42.0	27.1	12.1	10.9	7.9
U.S. Population 1998	30.5	29.7	16.1	11.4	12.1
Eligible for Free Lunch					
Mathematics 1996	59.4	19.0	5.0	7.9	8.7
Writing 1998	46.9	23.0	7.5	8.0	14.6
Not Eligible for Free Lunch					
Mathematics 1996	34.7	31.3	15.2	11.2	7.7
Writing 1998	22.6	33.6	20.2	12.8	10.8
No Information					
Mathematics 1996	31.4	29.5	16.1	15.8	7.2
Writing 1998	21.6	30.6	21.7	14.2	12.0
Male					
Mathematics 1996	41.8	27.7	11.5	11.0	8.1
Writing 1998	30.0	30.9	16.0	10.7	12.4
Female					
Mathematics 1996	42.2	26.5	12.8	10.8	7.8
Writing 1998	31.1	28.4	16.3	12.1	12.1
White					
Mathematics 1996	36.5	30.4	14.7	11.5	7.0
Writing 1998	26.4	33.0	18.8	11.8	9.9
Black					
Mathematics 1996	55.5	15.8	5.1	10.3	13.3
Writing 1998	38.3	21.7	9.6	10.3	20.2
Hispanic					
Mathematics 1996	55.8	23.0	6.5	7.3	7.4
Writing 1998	43.7	22.2	9.8	9.6	14.7
Asian American					
Mathematics 1996	32.5	27.0	16.1	18.3	6.0
Writing 1998	21.3	30.8	19.8	16.7	11.4
American Indian					
Mathematics 1996	50.4	27.1	6.5	10.7	5.2
Writing 1998	35.7	25.6	13.3	9.8	15.6

There is essentially no gender gap regarding possession of a computer at home or frequency of its use for schoolwork. However, the proportion of students with computers at home is far from uniform across race/ethnicity or social class groups. A substantially greater proportion of economically advantaged, white, and Asian American fourth-grade students have computers at home than do economically disadvantaged, Black, Hispanic, and American Indian fourth-grade students. Although the gap in home computer ownership between whites and minority groups has closed somewhat between 1996 and 1998, during 1998, a greater proportion of Black and Hispanic fourth-grade students lived in homes without computers than did white fourth-grade students in 1996.

In spite of the fact that fewer economically disadvantaged, Black, Hispanic, and American Indian fourth-grade students have computers at home, they are likelier than other groups to report that they use computers every day for schoolwork.

Table 14 gives the relation between student-reported computer use at home for schoolwork and free- or reduced-price lunch eligibility, gender, and race/ethnicity for eighth-grade students based on the 1996 assessment in mathematics and the 1998 assessment in writing. As was true for fourth-grade students, there has been a substantial overall decline in the proportion of eighth-grade students who had no computer at home (from 35.7 percent nationally to 24.3 percent).

Table 14. Student Reported Home Computer Use for Schoolwork in 1996 and 1998 by SES, Gender, and Race/Ethnicity (Grade 8)

	Grade 8 Home Computer Use (%)				
	No Computer at Home	Never or Hardly Ever	Once or Twice a Month	Once or Twice a Week	Every Day
U.S. Population 1996	35.7	15.3	19.0	18.3	11.7
U.S. Population 1998	24.3	15.1	22.0	20.6	18.0
Eligible for Free Lunch					
Mathematics 1996	58.1	13.3	10.8	9.7	8.1
Writing 1998	43.7	17.6	13.7	12.5	12.5
Not Eligible for Free Lunch					
Mathematics 1996	28.1	16.0	23.1	20.6	12.2
Writing 1998	17.8	14.6	25.3	22.7	19.6
No Information					
Mathematics 1996	26.7	15.7	18.2	23.6	15.7
Writing 1998	16.7	12.8	23.8	25.8	20.9
Male					
Mathematics 1996	34.1	16.8	17.9	17.3	13.9
Writing 1998	23.4	16.7	20.8	19.4	19.8
Female					
Mathematics 1996	37.5	13.7	20.2	19.3	9.4
Writing 1998	25.3	13.5	23.2	21.9	16.2
White					
Mathematics 1996	30.6	15.4	21.2	20.1	12.6
Writing 1998	19.4	14.6	24.3	22.7	19.0
Black					
Mathematics 1996	49.2	14.9	13.9	12.7	9.2
Writing 1998	34.2	18.9	17.0	14.9	15.0
Hispanic					
Mathematics 1996	50.0	16.2	12.5	12.9	8.4
Writing 1998	41.7	15.4	14.9	14.3	13.7
Asian American					
Mathematics 1996	31.8	12.9	18.5	23.4	13.4
Writing 1998	15.6	7.7	24.7	26.6	25.6
American Indian					
Mathematics 1996	57.7	12.1	9.6	8.9	11.7
Writing 1998	34.1	18.7	14.1	15.6	17.5

At grade 8, the gender gap in possession of a computer at home and the frequency of its use for schoolwork is relatively small (about 2–3 percent), with greater computer availability and use reported by males. Similar to the fourth grade, the proportion of eighth-grade students who report using computers at home is far from uniform across race/ethnicity or social class groups.

Unlike the data we examined on fourth-grade students, economically disadvantaged (those eligible for free- or reduced-price lunch), Black, Hispanic, and American Indian eighth graders are *less* likely than the economically advantaged, white, or Asian American students to report that they use the computers every day or every week at home for schoolwork.

Table 15 gives the relation between student-reported computer use at home for schoolwork and free- or reduced-price lunch eligibility, gender, and race/ethnicity for twelfth-grade students based on the 1996 assessment in mathematics and 1998 assessment in writing. As was true for fourth- and eighth-grade students, there has been an overall decline in the proportion of twelfth-grade students who had no computer at home (from 29.6 percent nationally to 24.3 percent).

Table 15. Student Reported Home Computer Use for Schoolwork in 1996 and 1998 by SES, Gender, and Race/Ethnicity (Grade 12)

	Grade 12 Home Computer Use (%)				
	No Computer at Home	Never or Hardly Ever	Once or Twice a Month	Once or Twice a Week	Every Day
U.S. Population 1996	29.6	15.4	24.3	19.8	10.9
U.S. Population 1998	24.3	12.3	23.4	22.2	17.8
Eligible for Free Lunch					
Mathematics 1996	58.0	14.8	11.5	10.3	5.3
Writing 1998	48.8	12.7	13.7	12.9	11.9
Not Eligible for Free Lunch					
Mathematics 1996	26.3	15.9	26.1	20.0	11.7
Writing 1998	20.7	12.7	25.0	23.3	18.3
No Information					
Mathematics 1996	23.0	14.6	26.5	24.3	11.7
Writing 1998	19.4	10.8	24.6	25.0	20.2
Male					
Mathematics 1996	27.5	17.5	22.9	19.3	12.8
Writing 1998	23.2	14.2	22.9	20.8	18.9
Female					
Mathematics 1996	31.4	13.5	25.5	20.3	9.2
Writing 1998	25.3	10.6	23.8	23.4	16.9
White					
Mathematics 1996	24.0	15.4	27.0	21.8	11.8
Writing 1998	19.1	12.6	25.6	24.2	18.5
Black					
Mathematics 1996	44.2	18.1	18.0	12.2	7.5
Writing 1998	37.6	14.0	19.4	15.5	13.5
Hispanic					
Mathematics 1996	46.2	13.8	18.4	13.8	7.9
Writing 1998	41.8	10.9	16.7	16.4	14.3
Asian American					
Mathematics 1996	22.0	8.5	19.8	33.8	15.9
Writing 1998	17.2	5.5	18.2	27.7	31.5
American Indian					
Mathematics 1996	55.7	21.1	7.1	10.3	5.7
Writing 1998	29.8	11.0	22.6	14.4	22.2

The gender gap regarding possession of a computer at home and the frequency of its use for schoolwork is relatively small (about 2–3 percent), with greater computer availability and use reported by males. Similar to the fourth and eighth grades, the proportion of twelfth-grade students who report using computers at home differs across race/ethnicity or social class groups. Indeed, twice as many economically disadvantaged Black, Hispanic, and American Indian twelfth-grade students report having no computer at home as do their economically advantaged white, or Asian American counterparts.

As with the data we examined on eighth grade students but unlike that for fourth-grade students, economically disadvantaged (those eligible for free- or reduced-price lunch), Black, Hispanic, and American Indian twelfth-grade students are *less* likely than their economically advantaged white or Asian American counterparts to report that they use computers every day or every week at home for schoolwork. This suggests a pattern of progressively less computer use at home for schoolwork among economically disadvantaged and minority students as they progress in school.

Computer Use at School in Mathematics Classes

The findings on the level of student-reported computer use in mathematics classes are reported in Table16. Perhaps one of the most surprising findings from the 1996 NAEP mathematics assessment is how few students actually report using computers in mathematics class at school. Over 55 percent of students (56.3 percent, 56.5 percent, and 58.3 percent, respectively at grades 4, 8, and 12) report never or hardly ever using computers in mathematics classes. Only about 13 percent at each grade level report using computers every day in mathematics class.

Table 16. Student Reported School Computer Use for Mathematics in 1996

		Student Reported School Computer Use in Mathematics Class			
	Mean Mathematics Achievement	Never or Hardly Ever	Once or Twice a Month	Once or Twice a Week	Every Day
U.S. Population					
Grade 4	224	56.3	10.5	19.6	13.6
Grade 8	272	56.5	15.2	15.6	12.7
Grade 12	304	58.3	15.4	12.5	13.9
Free Lunch (Grade 4)					
Eligible	207	57.2	8.1	19.9	14.8
Not Eligible	280	54.3	16.6	15.9	13.2
Free Lunch (Grade 8)					
Eligible	252	62.5	11.8	15.5	10.2
Not Eligible	280	54.3	16.6	15.9	13.2
Free Lunch (Grade 12)					
Eligible	281	57.9	15.6	13.1	13.4
Not Eligible	307	58.8	14.9	12.1	14.2
Gender (Grade 4)					
Male	226	55.9	10.3	19.9	14.0
Female	222	56.6	10.8	19.4	13.2
Gender (Grade 8)					
Male	272	54.2	15.3	15.7	14.8
Female	272	54.2	15.3	15.7	14.8
Gender (Grade 12)					
Male	305	55.1	16.1	14.1	14.8
Female	303	61.1	14.8	11.0	13.1
Race/Ethnicity (Grade 4)					
White	232	56.7	11.7	19.7	12.0
Black	200	50.4	7.8	20.9	21.0
Hispanic	206	60.1	7.6	19.0	13.3
Asian American	232	57.0	9.6	18.9	14.5
Race/Ethnicity (Grade 8)					
White	282	56.4	15.9	14.6	13.1
Black	243	51.9	15.1	21.2	11.8
Hispanic	251	62.0	12.0	15.0	11.0
Asian American	274	55.7	13.8	14.3	16.3
Race/Ethnicity (Grade 12)					
White	311	57.9	15.6	12.6	13.9
Black	280	56.5	15.7	12.2	15.5
Hispanic	287	65.8	13.2	9.9	11.0
Asian American	319	57.6	14.2	16.2	12.0

Patterns of computer use in mathematics class are quite consistent for economically disadvantaged and advantaged students (as operationalized by free- or reduced-price lunch eligibility) in grades 4 and 12, but seem to differ somewhat in grade 8. In grade 8, students who are eligible for free- or reduced-price lunch report being likelier to never or hardly ever use computers and less likely to use them often than are students who are not eligible for free- or reduced-price lunch.

Patterns of computer use in mathematics class differ somewhat by gender, but differ substantially by race and ethnicity. At all three NAEP grade levels, Hispanic students are likelier to report never or hardly ever using computers in mathematics class than the other groups, with 60.1 percent, 62.0 percent, and 65.8 percent reporting no, or extremely limited, computer use at grades 4, 8, and 12, respectively. At grades 4 and 8, Black students are likelier to report computer use at least once a week than are other groups. At grade 4, for example, 41.9 percent of Black students report computer use at least once a week compared with only 31.7 percent of white students, 32.3 percent of Hispanic students, and 33.4 percent of Asian American students. Similarly, at grade 8, 33.0 percent of Black students report computer use at least every week compared with only 27.7 percent of white students, 26.0 percent of Hispanic students, and 30.6 percent of Asian students. But by grade 12, these differences narrow substantially so that 27.7 percent of Black students report computer use in mathematics class at least once a week, while 26.5 percent of white students, 20.9 percent of Hispanic students, and 28.2 percent of Asian American students so report. The increase in the computer use gap for Hispanic students at grade 12 is particularly striking.

The findings on the level of teacher-reported availability of computers in mathematics classes are reported in Table 17. It is interesting that the 1996 NAEP mathematics assessment suggests that computers are much more available in grade 4 mathematics classes than at grade 8. Only 20 percent of teachers of fourth-grade students, but 50.9 percent of teachers of eighth-grade students, report having difficult or no access to computers. Similarly, 63.2 percent of the teachers of fourth-grade students, but only 30.2 percent of the teachers of eighth-grade students, report having one or more computers in the classroom.

Table 17. Teacher Reported Availability of Computers in Mathematics Class in 1996

	Mean Mathematics Achievement	Teacher Reported Availability of Computers in Mathematics Class (%)			
		None Available	One or More in Classroom	In Lab, Difficult to Access	In Lab, Easy to Access
U.S. Population					
Grade 4	224	5.9	63.2	14.1	16.8
Grade 8	272	24.3	30.2	26.6	18.9
Free Lunch (Grade 4)					
Eligible	207	9.1	59.8	16.2	14.9
Not Eligible	231	4.1	66.9	10.8	18.3
Free Lunch (Grade 8)					
Eligible	252	23.9	34.2	26.8	15.1
Not Eligible	280	28.4	25.4	27.9	18.3
Gender (Grade 4)					
Male	226	6.5	62.4	13.9	17.4
Female	222	5.4	64.1	14.3	16.2
Gender (Grade 8)					
Male	272	22.9	29.3	28.8	19.1
Female	272	25.7	31.2	24.2	18.7
Race/Ethnicity (Grade 4)					
White	232	4.4	64.2	13.4	17.9
Black	200	11.3	58.5	18.8	11.4
Hispanic	206	7.3	63.7	10.9	18.1
Asian American	232	5.5	56.4	24.4	13.8
Race/Ethnicity (Grade 8)					
White	282	25.2	29.4	26.6	18.9
Black	243	18.5	35.1	28.7	17.7
Hispanic	251	27.3	26.5	24.9	21.3
Asian American	274	18.1	34.0	27.6	20.2

Patterns of computer availability in mathematics class are different for economically disadvantaged and advantaged students, but the differences go in the opposite direction in grade 4 than in grade 8. At grade 4, economically disadvantaged students have *less* computer availability than economically advantaged students. However, at grade 8, the pattern seems reversed and economically disadvantaged students have *greater* availability of computers than economically advantaged students.

The pattern of teacher-reported computer availability by race and ethnicity is complicated, but is roughly consistent with the pattern of computer access by free lunch eligibility. Teachers of Black students report less access to computers than teachers of white or Hispanic students in grade 4, but the pattern is reversed in grade

8, with teachers of Black and Asian American students reporting greater access to computers than teachers of white and Asian American students.

The pattern of primary uses of computers reported by teachers is given in Table 18. Note that teachers of grade 4 report that computers are most frequently used for mathematical learning games, whereas grade 8 teachers report that computers are most frequently used for drill and practice.

Table 18. Teacher Reported Primary Use of Computers in Mathematics Class in 1996

		Teacher Reported Primary Use of Computers in Mathematics Class (%)			
	Mean Mathematics Achievement	Drill and Practice	Demo of New Topics	Playing Mathematics Games	Simulations/ Applications
U.S. Population					
Grade 4	224	27.0	1.6	41.0	5.7
Grade 8	272	15.8	4.2	13.4	12.5
Free Lunch (Grade 4)					
Eligible	207	28.6	1.9	41.0	3.6
Not Eligible	231	27.1	1.3	43.6	6.4
Free Lunch (Grade 8)					
Eligible	252	15.8	4.1	15.9	10.2
Not Eligible	280	14.2	4.9	11.8	15.0
Gender (Grade 4)					
Male	226	27.7	2.1	40.3	5.2
Female	222	26.3	1.1	41.8	6.1
Gender (Grade 8)					
Male	272	16.4	4.4	13.4	13.0
Female	272	15.0	4.1	13.4	11.9
Race/Ethnicity (Grade 4)					
White	232	26.6	1.6	42.3	5.7
Black	200	30.2	2.5	34.4	5.0
Hispanic	206	26.2	1.1	43.0	5.7
Asian American	232	23.6	0.0	38.4	5.4
Race/Ethnicity (Grade 8)					
White	282	14.1	5.2	12.4	13.9
Black	243	25.9	2.0	15.6	6.8
Hispanic	251	13.9	2.2	14.9	10.2
Asian American	274	11.6	1.9	10.8	18.1

The primary use of computers reported by teachers does not vary substantially according to economic status of the student. At grade 4, there is not a substantial difference in the use of computers reported by teachers of students eligible for free- or reduced-price lunch and those who are not eligible. In grade 8 mathematics classes, the most substantial difference by economic status occurs between the primacy of playing mathematical learning games versus simulations and applications. Among those eligible for free- or reduced-price lunch, playing mathematical learning games is most frequent for 15.9 percent of students versus 10.2 percent for whom simulations and applications are most frequent. The corresponding percentages for those *not* eligible for free- or reduced-price lunch are 11.8 percent and 15.0 percent, respectively.

The pattern of differences by race or ethnicity suggests that, at both grades 4 and 8, teachers of Black students more frequently use computers primarily for drill and practice than do teachers of other groups. At grade 8, teachers of Black and Hispanic students primarily use computers for mathematical learning games somewhat more often, and simulations and applications somewhat less often, than teachers of whites and Asian American students.

Computer Use at School for Reading Instruction

The findings on the level of teacher-reported use of computer software for reading instruction is reported in Table 19. Perhaps one of the most surprising findings from the 1998 NAEP assessment in reading is how few students have teachers who report using computer software for reading instruction at school. The teachers of 58.5 percent of students at grade 4, and 78.5 percent of students at grade 8, report *never or hardly ever* using computer software for reading instruction. Just over 24 percent at grade 4, and 7.3 percent at grade 8, report using computer software for reading instruction at least once a week.

Table 19. Teacher Reported Computer Software Use for Reading Instruction in 1998

		Teacher Reported Computer Software Use for Reading Instruction			
	Mean Reading Achievement	Never or Hardly Ever	Once or Twice a Month	Once or Twice a Week	Every Day
U.S. Population					
Grade 4	217	58.5	17.4	15.8	8.3
Grade 8	264	78.5	14.3	4.5	2.8
Free Lunch (Grade 4)					
Eligible	198	52.2	14.1	21.8	11.9
Not Eligible	227	59.7	21.1	12.9	6.3
Free Lunch (Grade 8)					
Eligible	246	74.8	14.5	6.2	4.5
Not Eligible	270	78.9	14.8	3.7	2.5
Gender (Grade 4)					
Male	214	58.2	17.8	15.5	8.5
Female	220	79.4	14.0	4.0	2.6
Gender (Grade 8)					
Male	257	77.5	14.6	5.0	2.9
Female	270	79.4	14.0	4.0	2.6
Race/Ethnicity (Grade 4)					
White	227	60.7	19.0	13.7	6.6
Black	194	52.2	12.4	22.4	13.0
Hispanic	196	53.8	15.7	18.7	11.8
Asian American	225	65.5	15.2	13.3	6.0
Race/Ethnicity (Grade 8)					
White	272	81.0	13.5	2.9	2.6
Black	243	69.4	18.5	10.0	2.1
Hispanic	244	72.7	14.8	7.3	5.2
Asian American	271	836.6	11.9	3.7	0.8

Patterns of computer use in language arts classes are different for economically disadvantaged and advantaged students use of computer software for reading instruction is more frequently reported by the teachers of the economically disadvantaged than of other students. At grade 4, teachers of Black students are less likely to report never using computers than teachers of white, Hispanic, or Asian students. Teachers of grade 8 Black and Hispanic students are also less likely to report never using computers.

The findings on the level of teacher-reported availability of computers are reported in Table 20. It is interesting that the 1998 NAEP reading assessment suggests that computers are much more available in grade 4 classrooms than for language arts classes at grade 8. Only 19.3 percent of reading teachers of fourth-grade students, but 41.5 percent of reading teachers of eighth-grade students, report having difficult or limited access to computers. Similarly, 66.2 percent of the teachers of fourth-grade students, but only 34.3 percent of the teachers of eighth-grade students, report having one or more computers in the classroom.

Table 20. Teacher Reported Availability of Computers for Their Classes in 1998 (Reading)*

		Teacher Reported Availability of Computers			
	Mean Reading Achievement	Not Available	Limited Access	Lab or Library Access	In-Class Access
U.S. Population					
Grade 4	217	6.2	13.1	14.5	66.2
Grade 8	264	11.1	30.4	24.2	34.3
Free Lunch (Grade 4)					
Eligible	198	7.5	11.4	13.8	67.3
Not Eligible	227	4.9	13.6	15.0	66.5
Free Lunch (Grade 8)					
Eligible	246	13.7	24.4	22.6	39.4
Not Eligible	270	8.4	32.7	25.1	33.8
Gender (Grade 4)					
Male	214	6.2	13.4	14.8	65.5
Female	220	6.2	12.8	14.2	66.8
Gender (Grade 8)					
Male	257	11.9	30.7	23.8	33.5
Female	270	10.2	30.1	24.6	35.1
Race/Ethnicity (Grade 4)					
White	227	5.5	13.7	14.7	66.1
Black	194	8.0	12.7	12.4	67.0
Hispanic	196	8.6	9.8	15.7	65.9
Asian American	225	3.8	16.9	17.7	61.6
Race/Ethnicity (Grade 8)					
White	272	9.4	33.9	25.3	31.5
Black	243	18.2	24.3	21.8	35.7
Hispanic	244	11.8	20.6	22.6	45.0
Asian American	271	8.9	27.5	22.2	41.3

* At grade 4, these classes were likely to be intact classrooms offering instruction in all subject areas. At grade 8, these classes were more likely to be specifically language arts classes.

Teachers of economically disadvantaged fourth-grade students report that computers are somewhat less available for their classes than for those of their economically advantaged counterparts. Teachers of 7.5 percent of economically disadvantaged fourth-grade students report that computers are not available, but only 4.9 percent of the teachers of other fourth-grade students so report. The same pattern is evident at grade 8. However, at grade 8, teachers of disadvantaged students are also likelier than teachers of other students to report that they have a computer in their classroom.

The pattern of teacher-reported computer availability by race and ethnicity is complicated, but is roughly consistent with the pattern of computer access by free-lunch eligibility. Teachers of Black and Hispanic students report less access to computers than teachers of white or Asian American students at grade 4. At grade 8, teachers of Black students are likelier to report no access to computers than teachers of white students, but also likelier to report having computers in the classroom.

Computer Use at School for Writing Instruction

The findings regarding the level of student-reported computer use for writing drafts or final versions of stories or reports are given in Table 21. These findings are surprising in several ways. First, they suggest that about 12 percent of students at each grade school are using computers for writing drafts or final versions of stories or reports *every day*. It is also surprising that, apparently, only about 25 percent of students in any grade (a little more in grade 4, a little less in grade 12) *never or hardly ever* use the computer for writing drafts or final versions of stories or reports. Correspondingly, about 75 percent of students report using computers *at least once a month* for this purpose.

Table 21. Student Reported Computer Use for Writing Drafts or Final Versions of Stories or Reports in 1998

		Student Reported Computer Use for Writing Drafts or Final Versions of Stories or Reports			
	Mean Writing Achievement	Never or Hardly Ever	Once or Twice a Month	Once or Twice a Week	Everyday
U.S. Population					
Grade 4	150	28.2	35.3	23.6	12.9
Grade 8	150	25.6	39.0	23.6	11.8
Grade 12	150	22.6	42.1	23.5	11.8
Free Lunch (Grade 4)					
Eligible	134	28.7	27.1	26.5	17.7
Not Eligible	158	28.4	39.2	21.8	10.7
Free Lunch (Grade 8)					
Eligible	132	29.6	32.6	24.3	13.5
Not Eligible	157	24.6	42.2	22.5	10.7
Free Lunch (Grade 12)					
Eligible	133	25.2	38.8	23.1	12.9
Not Eligible	152	22.3	43.3	23.2	11.1
Gender (Grade 4)					
Male	142	28.8	35.7	23.1	12.4
Female	158	27.8	24.8	23.8	13.6
Gender (Grade 8)					
Male	140	27.2	37.0	22.8	13.0
Female	160	24.0	41.1	24.4	10.6
Gender (Grade 12)					
Male	140	25.5	39.9	22.6	11.9
Female	159	20.0	44.1	24.3	11.6
Race/Ethnicity (Grade 4)					
White	157	30.2	38.6	21.3	9.9
Black	131	23.4	24.8	28.5	23.3
Hispanic	134	24.5	28.8	28.3	18.4
Asian American	164	25.3	27.4	26.2	11.1
Race/Ethnicity (Grade 8)					
White	158	25.9	41.5	22.5	10.1
Black	131	25.8	31.5	25.0	17.7
Hispanic	131	26.8	32.5	26.8	13.9
Asian American	159	16.0	42.1	29.3	12.6
Race/Ethnicity (Grade 12)					
White	156	21.8	44.0	23.6	10.6
Black	134	25.9	38.6	21.1	14.4
Hispanic	135	26.1	36.3	23.8	13.9
Asian American	152	15.1	40.3	29.9	14.7

The relation of free- or reduced-price lunch eligibility to frequency of computer use for writing drafts or final versions of stories or reports is quite consistent across grades. At each of the three NAEP grade levels, students eligible for free- or reduced-price lunch are likelier to report computer use for writing drafts or final versions of stories or reports at least weekly and also likelier to report *never or hardly ever* using computers for this purpose. The differences in reports of frequent use are largest at grade 4 and smallest at grade 12.

Patterns of computer use for writing drafts or final versions of stories or reports differ substantially by race and ethnicity. At all three NAEP grade levels, white students are less likely to report use of the computer for writing drafts or final versions of stories or reports at least weekly than are other students. Since using computers for writing drafts or final versions of stories or reports would appear to demonstrate a high-level use of computers, this indicates that high-level computer use in writing instruction is available to minority students.

Unfortunately, not all the computer use in writing could be classified as high level. Table 22 presents data on student-reported use of computers for doing spelling, punctuation, and grammar exercises. Although this use of computers in writing instruction is reported less frequently than computer use for writing drafts or final versions of stories or reports, it is reported more frequently for the economically disadvantaged and for non-whites (especially for Blacks and Hispanics) at every NAEP grade level. The rate of computer use for low-level writing instruction (for spelling, punctuation, and grammar exercises) among the economically disadvantaged and for non-whites is typically higher than the rate of high-level computer use for writing (for writing drafts or final versions of stories or reports) for the same groups.

Table 22. Student Reported Computer Use for Doing Spelling, Punctuation, or Grammar Exercises in 1998

		Student Reported Computer Use for Doing Spelling, Punctuation, or Grammar Exercises			
	Mean Writing Achievement	Never or Hardly Ever	Once or Twice a Month	Once or Twice a Week	Everyday
U.S. Population					
Grade 4	150	35.6	11.9	26.1	26.4
Grade 8	150	47.5	17.2	19.8	15.4
Grade 12	150	55.4	16.4	15.6	12.6
Free Lunch (Grade 4)					
Eligible	134	28.5	9.1	26.1	36.3
Not Eligible	158	39.1	13.7	26.1	21.1
Free Lunch (Grade 8)					
Eligible	132	39.9	16.5	22.5	21.1
Not Eligible	157	49.7	18.2	18.7	13.4
Free Lunch (Grade 12)					
Eligible	133	46.0	16.4	19.1	18.6
Not Eligible	152	57.2	16.7	14.8	11.3
Gender (Grade 4)					
Male	142	34.1	12.4	26.9	26.6
Female	158	37.0	11.5	25.3	26.1
Gender (Grade 8)					
Male	140	45.5	16.4	20.8	17.3
Female	160	49.5	18.0	19.0	13.6
Gender (Grade 12)					
Male	140	53.9	16.6	16.7	12.9
Female	159	56.9	16.3	14.6	12.3
Race/Ethnicity (Grade 4)					
White	157	39.9	13.1	25.3	21.7
Black	131	35.5	14.8	24.1	25.6
Hispanic	131	38.1	15.9	24.5	21.6
Asian American	159	43.5	21.5	21.8	13.2
Race/Ethnicity (Grade 8)					
White	158	51.9	17.8	17.9	12.4
Black	131	35.5	14.8	24.1	25.6
Hispanic	131	38.1	15.9	24.5	21.6
Asian American	159	43.5	21.5	21.8	13.2
Race/Ethnicity (Grade 12)					
White	156	60.0	16.2	13.6	10.2
Black	134	46.2	17.3	18.2	18.3
Hispanic	135	44.0	16.6	21.1	18.4
Asian American	152	42.5	17.6	23.8	16.1

The findings on the level of teacher-reported availability of computers in classes where writing is taught are reported in Table 23. It is interesting that the 1998 NAEP writing assessment suggests that computers are widely available in grade 4 (teachers of only 19.6 percent of students report limited or no access) but less so at grade 8 (teachers of 42.9 percent of students report limited or no access).

Table 23. Teacher Reported Availability of Computers for Their Classes in 1998 (Writing)*

		Teacher Reported Availability of Computers			
	Mean Writing Achievement	Not Available	Limited Access	Lab or Library Access	In Class Access
U.S. Population					
Grade 4	150	5.6	14.0	15.2	65.1
Grade 8	150	12.3	30.6	23.3	33.9
Free Lunch (Grade 4)					
Eligible	134	7.1	11.2	14.6	67.0
Non Eligible	158	4.7	13.3	15.9	66.1
Free Lunch (Grade 8)					
Eligible	132	13.6	25.0	23.0	38.5
Not Eligible	157	10.1	31.8	24.6	33.4
Gender (Grade 4)					
Male	142	5.5	13.5	15.2	65.8
Female	158	5.7	14.4	15.2	64.8
Gender (Grade 8)					
Male	140	12.0	30.6	23.3	34.1
Female	160	12.6	30.5	23.3	33.6
Race/Ethnicity (Grade 4)					
White	157	4.6	14.5	15.9	64.9
Black	131		11.6	13.3	65.6
Hispanic	134	6.2	12.8	13.9	67.0
Asian American	164	5.1	19.8	15.0	60.1
Race/Ethnicity (Grade 8)					
White	158	11.6	33.2	24.4	30.8
Black	131	15.5	28.1	20.7	35.7
Hispanic	131	13.4	21.8	20.7	44.1
Asian American	159	8.1	24.9	23.6	43.3

* At grade 4, these classes were likely to be intact classrooms offering instruction in all subject areas. At grade 8, these classes were more likely to be specifically language arts classes.

There is little difference between the reports of computer availability at grade 4 for economically disadvantaged and advantaged students. However, at grade 8, teachers of economically disadvantaged students are likelier to report access to computers in class and less likely to report limited or no access to computers.

As with mathematics and reading instruction, the pattern of teacher-reported computer availability by race and ethnicity is complicated, but is roughly consistent with the pattern of computer access by free lunch eligibility. Teachers of Black students are likelier to report no access to computers than teachers of white, Hispanic, or Asian American students in grade 4. At grade 8, teachers of Black and Hispanic students are likelier to report no access to computers, but also likelier to report access to computers in the classroom than teachers of white students. Of all groups, teachers of Hispanic and Asian American students report the highest levels of in-class access to computers.

The Relation of Computer Use to Academic Achievement

The design of the NAEP data collection process poses problems for drawing inferences about causal relations from its data, and limits the degree of confidence that can be applied to causal conclusions. After considerable investigation and modeling work, we concluded that, given the weaknesses of NAEP data for causal inference, even tentative conclusions about the relation of achievement and computer use on the basis of the NAEP data are not warranted. We summarize below the nature of the limitations that led to this conclusion.

Weaknesses of NAEP As a Data Source for Studying the Effects of Technology on Achievement

NAEP has two major limitations as a source of data for drawing inferences about causal relations. First, NAEP is a cross-sectional survey. Second, the measurement of key non-achievement (background) variables in NAEP is weak.

It is key to keep in mind that NAEP is a one-point-in-time cross-sectional survey. While this design is appropriate and efficient for assessing achievement status (the major purpose of NAEP), it poses problems for the inference of causal relations between variables measured at the same point in time. In particular, it is difficult to determine the direction of cause. For example, do differences in computer use cause achievement differences or do achievement differences cause differences in computer use? To put it another way, there is a very plausible rival hypothesis that could explain any relation found between computer use and achievement. While it might be that computer use influences achievement, it is also plausible that students are selected to have certain patterns of computer use because of their achievement. This could take the form of assigning low-achieving students to more frequent computer use than other student populations as a compensatory strategy. In such a case, one might find a spurious relation between computer use and achievement, much as one finds that elementary school students who spend more time doing homework do less well in school.

A longitudinal study design that permits the examination of changes in achievement over time as a function of explanatory variables such as computer use would provide information about causality that would be much less ambiguous (albeit much less efficient for the purposes of assessment of current status, which is the primary mission of NAEP). Probability sampling can provide good evidence for generalizing findings in longitudinal surveys. However, the data from longitudinal surveys are not completely unambiguous regarding causal factors associated with change. They do not rule out the possibility that relations are confounded by other factors. For example, if differences in achievement gains are actually caused by differences in school resources or social capital, and the latter is related to computer use, there would be an apparent relation between computer use and achievement gains—a spurious relation that would not necessarily be discovered from analyses of a longitudinal survey.

Of course, if the mechanisms underlying the creation of academic achievement were understood completely, and if each of the variables was measured well, then a longitudinal survey (or even a cross-sectional one) could provide adequate information on causal effects. Analyses of NAEP, or any other cross-sectional survey that attempts to determine causal relations, must make assumptions about such mechanisms. It is clear that some aspects of the mechanisms that produce academic achievement are elusive. Though educational researchers have made considerable progress in identifying key aspects of these mechanisms, there is not consensus about all of them.

Randomized experiments would provide less ambiguous data about causality than longitudinal surveys. Well-implemented experiments have the great virtue of providing valid causal inferences in the absence of knowledge of the mechanisms that generate achievement. Randomized experiments with multiple waves of data collection (longitudinal experiments) can provide even more compelling evidence. However, randomized experiments (unless they are conducted on probability samples) do not necessarily provide results that can be generalized to a well-defined universe of settings other than those in which they were conducted. That is, randomized experiments may provide locally valid causal inferences, but they do not necessarily generalize elsewhere. Randomized experiments on probability samples or on a large enough scale to make (non-probability based) claims of being representative are possible, but difficult, expensive, and time-consuming. However, when conducted, they can provide evidence that is extremely compelling, as in the case of the Tennessee class size experiment (see, e.g., Nye, Hedges, and Konstantopoulos, 1999).

Also note that measurement of key variables is weak in NAEP, as opposed to the sound measurement of academic achievement, which is a strong point of NAEP. However, any hope of causal inferences from cross-sectional surveys like NAEP depends on knowledge of the mechanisms that lead to achievement, and adequate measurement of important variables that are implicated in those mechanisms. Poor measurement of important variables implies that estimates of causal effects are biased even if the mechanisms are known. Therefore, it is important to evaluate the quality of measurement of key non-achievement or background variables in NAEP. Unfortunately, as noted, the measurement of many of the background variables is not nearly as adequate in NAEP as is the measurement of achievement. Again, this is reasonable, given that the primary mission of NAEP is to measure achievement of students in the nation as a whole and of a few important demographic subgroups within the nation.

Overall Recommendations

Based on this research, we propose that several recommendations are warranted. Some of these recommendations are relatively minor, and could easily be implemented without substantial additional resources. Others would involve more substantial commitments of resources.

Recommendation 1: Treat the design, validation, and production of background items with as much care as the cognitive items.

Recommendation 1A: Question Design Could Be Improved. It is clear that the field of educational technology has evolved very quickly. However, large-scale assessments operate in cycles of development and analysis that span years. This makes it very difficult to anticipate which questions will be of the greatest interest by the time the data obtained are finally analyzed, which is usually years after the questions were written. In this case, the strategy for designing the computer use questions is unclear. For example, content (e.g., assessed subject matter or not), location (e.g., computer use at home or at school), and amount of time spent using the computer (time on task) could be used to provide one logical design framework around which computer use might be measured. No doubt, there are wiser design frameworks. Questions designed around a more specific framework would yield more useful information about computer use and its relationship to achievement. In any event, more specific and consistent questions would be a valuable step forward.

For example, the NAEP 1996 assessment in mathematics student questionnaire asks how often students "use a computer at home for schoolwork," and how often they "use a computer when they do mathematics at school." The intent of each question was unclear. The first question may have been intended to elicit general information about computer use for all schoolwork in all subjects, not just mathematics. Such a question may well yield valuable information. However, we believe it would be useful to ask also (or to ask instead) how often students "use a computer at home for schoolwork in mathematics" (or some other construction that specifically targets at-home use of computers for mathematics schoolwork). Such a question, in addition to the question about using computers for mathematics at school, would provide a more complete picture of how computers are being applied in mathematics learning.

Similarly, the student questionnaire for the NAEP 1998 assessment in reading asks how often the student "uses a computer for schoolwork," but does not specifically mention *at home* use. Thus, this question does not explicitly distinguish home computer use for schoolwork from school computer use. We believe that it would be desirable to do so. Moreover, it does not specify if the computer use is for reading or some other subject matter. Again, the intent of the questions is unclear. Is it intended to measure general computer use in any subject matter? If so, it would be desirable in a reading assessment to have a question that focuses entirely on computer use in reading or language arts.

One advantage of a non-subject matter specific question about computer use is that it might provide a basis for comparing computer usage in different years.

However, we noted that the 1996 assessment in mathematics and the 1998 assessment in reading student questionnaires does not ask the same general questions about computer use. As noted above, the 1996 questionnaire asks how often students "use a computer *at home* for schoolwork" (italics added), but the 1998 assessment in reading asks how often students "use a computer for schoolwork." Thus, a comparison between the rates of computer use in 1996 and 1998 is not possible from these data. We did note that the 1998 assessment in writing used the same question for home computer use as did the 1996 assessment in mathematics, so a comparison of these data is possible, but it is unclear if this was a deliberate design feature or a mere coincidence.

Recommendation 1B: Question Validation Could Be Improved. We do not know the extent to which computer use questions were validated prior to their use in the assessment, but some of the data raises validity concerns. First, the ambiguity of some of the questions raises validity concerns because the intent of the questions may be unclear to respondents. For example, do questions in a mathematics assessment that refer to schoolwork intend to measure schoolwork in just *mathematics*, or do they refer to all schoolwork? Similarly, when a question about using a computer appears among various questions about the home and family, will it be interpreted to mean computer use *at home* or both *at home* and *at school*? Our initial readings of these questions did not reveal the nuances in the actual text of the questions, and it seems plausible that students (particularly fourth and eighth graders) might also fail to grasp the intended meaning of the questions.

The rather low level of agreement between student reports of computer use and teacher reports of computer use also raises validity concerns. While the disagreements observed may be *logically* possible if both variables are perfectly valid, they do seem implausible. A serious effort to validate the computer use questions is warranted.

Note that in other NAEP student background questions querying students on frequency of events, the validity of *every day* as a response has been questioned. For example, when fourth-grade students were questioned on the frequency of writing assignments of three or more pages, their answers of *every day* seem unlikely to be valid. Students—particularly minority and low SES students—reported a surprisingly high frequency of computer use "every day." This may reflect a real phenomenon, but might also reflect a validity problem that is exaggerated among these groups.

Recommendation 1C: Production Could Be Improved. In our analyses of a rather limited set of background items, we found a number of cases where it appeared that background items were incorrectly printed, were inconsistent from grade to grade, or from assessment to assessment. For example, the item about whether the father worked outside the home for pay seems to have been misprinted (at least in booklets M107G and M105CY). One of the response alternatives for question 26, "Does either your father or stepfather work at a job for pay?" is "I don't live with either my father or step*mother*." Unfortunately, with this response alternative, the question yields ambiguous data about the father or stepfather's labor force participation. We suspect that the response alternative was intended to read, "I don't live with either my father or step*father,*" which would have yielded clear information.[3]

Similarly, Part IIB of the 1998 language arts teacher questionnaires has two questions on the ability level of the class of each student being assessed. The fourth-grade teacher questionnaire asks about the "reading ability level" (question 3) and "writing ability level" (question 7). The eighth-grade teacher questionnaire asks about the "ability level" without specifying *reading* ability level (question 2), but does ask specifically about "writing ability level" (question 7). The CD-ROM containing the data set labels the first variable as "ability level" at both grade levels. The question in this category, however, differs between fourth and eighth grades. We suspect that the question was intended to be identical at the two grade levels, but it was not. The vagueness of the question at grade 8 makes it more difficult to interpret and renders the data in grades 4 and 8 unfit for comparison.

Recommendation 2: Consider developing teacher questionnaire items that would obtain information about the specific computer software and hardware used.

One of the problems in interpreting the results of NAEP data on computer use is that we have very few details about computer use. Indeed, we suspect that the reason computer use is not clearly linked to achievement is because of the way that the computer is being used is correlated with *how often* it is being used. Previous research (and common sense) indicates that computer software is a critical component in determining whether computer use is a tool that enhances achievement. Without knowing which software is being used, it is difficult to determine the quality of the instructional experience. One possible solution is to develop a more detailed set of questions about the capabilities of the software. Another strategy is to ask teachers to provide the name (and edition) of computer software they are using. This could permit NAEP or secondary analysts to do their own coding of software capabilities.

Similarly, it is difficult to interpret data on computer use without knowing what computer hardware is available to teachers and students. Hardware not only imposes limitations on the software that can be used, it may determine whether teachers attempt to use computers at all. They may not do so if the hardware is too antiquated to effectively run desirable software. Pertinent to these concerns is the availability of Internet access and networking capability, since access to the Internet is an increasingly important educational tool. As when suggesting software usage questions, one might develop a more detailed set of questions about hardware capabilities. Another (not necessarily alternative) possibility is to ask teachers for the name (and edition) of computer hardware and networking applications they are using.

[3] This particular production problem was discovered by NAEP staff before the assessment was conducted, but after the booklets were printed. The decision was made that it was a sufficiently minor problem that reprinting of booklets and possible delay of the assessment was not warranted.

Recommendation 3: Consider supplementing the NAEP design with an in-depth study of a small sample of schools.

It is difficult to obtain a detailed picture of computer use in schools from the data now collected. Any feasible enhancements to the teacher and student questionnaires will yield only marginal improvements. More conclusive evidence might be obtained by studying actual computer use in a sub-sample of NAEP schools for a short period before or after the assessment. The actual design of such a study would have to be carefully planned, but could involve either detailed interviews, teacher logs, or observations of computer use over a period of at least several days. Such a study could greatly enhance knowledge about how computers are actually being used and how those uses might relate to achievement. Note that such a study need not be conducted before the assessment (which might prompt fears that it would compromise the validity of the NAEP cognitive data). Detailed data on computer use could be collected *after* the cognitive data collection, which would make it just as useful for descriptive purposes and only marginally less useful for association with NAEP cognitive results.

Recommendation 4: Consider a multi-site experiment to determine how teachers and students are using computers and the impact of computers on achievement.

Surveys like NAEP have substantial limitations as sources of information about cause and effect. NAEP is ideally suited to assess the frequency of computer use and the level of academic achievement of various groups of students. However, it cannot provide definitive evidence about the relation between computer use and achievement. A randomized experiment would be a much more persuasive source of such information. While large-scale experiments in education are difficult to carry out, they are not impossible, and, when they have been conducted, they have had extraordinary influence (as in the case of the Tennessee class size experiment).

We propose that the U.S. Department of Education consider a carefully designed, randomized experiment to determine how computers are being used in schools and what effects they produce on student achievement. Because the effects are likely to be subtle and may vary across school contexts, we recommend inclusion of a diverse set of schools in the sample. The schools should ideally represent the spectrum of schools in the U.S. with respect to social class, racial and ethnic composition, and community contexts. The sample should also be geographically diverse, including urban, suburban, and rural areas.

Because it takes time to change patterns of instruction and student learning, we recommend that such an experiment be longitudinal, examining patterns of computer use and student achievement over a period of several years. Such a longitudinal experiment could provide insight about how educational technology changes schools, as well as how technology's effects on students may change over time.

Such a randomized experiment might involve other design factors beyond computer use. It would also be possible to vary the density of technology in a school, the amount of in-service training for teachers, the degree of ongoing support teachers receive in technology use, the type of software provided, etc.

Finally, we recommend a modest follow-up study be conducted after the experiment concludes to examine the long-term benefits of technology use. Analyses of long-term effects can be important evidence for policy decisions.

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Appendix A:

Exact Text of Questions on Computer Use: 1996 NAEP Mathematics Assessment[4]

Student Reports of Frequency of Computer Use

There are two questions on the Student Questionnaire about computer use. The first asks about general use of computers at home for school work (not necessarily related to mathematics). The question is:

"How often do you use a computer at home for schoolwork?"

The second question is:

"When you do mathematics in school, how often do you use a computer?"

The possible responses for both these questions are:
a) Almost every day
b) Once or twice a week
c) Once or twice a month
d) Never or hardly ever
e) There is no computer at home.

Teacher Reports of Frequency of and Type of Computer Use

In addition, the teacher questionnaire has two questions related to computer use in some way. The first question is:

"How often do the students in this class do each of the following?"

One of the thirteen activities is: *"Use a computer."*

The possible responses are:
a) Almost every day
b) Once or twice a week
c) Once or twice a month
d) Never or hardly ever

The second question is:
"If you do use computers, what is the primary use of these computers for mathematics instruction?"

[4] Student reports are available for all three grades (4, 8, and 12), but teacher reports are available only for grades 4 and 8.

The possible responses are:
a) Drill and practice
b) Demonstration of new topics in mathematics
c) Playing mathematical/learning games
d) Simulations and applications
e) I do not use computers for instruction.

Teacher Reports of Access to Computers at School

The question is:

"Which best describes the availability of computers for use by students in your mathematics classes?"

The possible responses are:
a) None available
b) One within the classroom
c) Two or three within the classroom
d) Four or more within the classroom
d) Available in a computer laboratory but difficult to access or schedule
e) Available in computer laboratory and easy to access or schedule

Appendix B:

Exact Text of Questions on Computer Use: 1998 NAEP Reading Assessment[5]

Student Reports of Frequency of Computer Use

There are two questions on the Student Questionnaire about computer use. The first question, asking about general use of computers for schoolwork (not necessarily related to reading), is:

"How often do you use a computer for schoolwork?"

The possible responses are:
a) Almost every day
b) Once or twice a week
c) Once or twice a month
d) Never or hardly never

The second question relates to computer use in libraries (not necessarily for use related to school subjects). The question is:

"How often do you use the school library or public library to do each of the following?"

One of four activities is: *"Use a computer."*

The possible responses are:
a) Almost every day
b) Once or twice a week
c) Once or twice a month
d) Once or twice a year
e) Never or hardly never

Teacher Reports of Frequency of and Type of Computer Use

In addition, the teacher questionnaire has two questions related to computer use in some way. The first question is:

"How often do you use the following resources to teach reading in this class?"
One of the resources listed is *"Computer software for reading instruction."*

[5] Student reports are available for all three grades (4, 8, and 12), but teacher reports are available only for grades 4 and 8.

The second question is:

"How often do you ask students in this class to do each of the following on a computer?"

One of the three activities is related to reading. It is:

"Read stories or do work related to reading instruction."

The two other activities are more pertinent to writing or language arts instruction. They are:

- *"Do spelling, punctuation, or grammar exercises"*
- *"Write drafts or final versions of stories or reports"*

The possible responses for both of these questions are:
a) Almost every day
b) Once or twice a week
c) Once or twice a month
d) Never or hardly never

Teacher Reports of Access to Computers

The question is:

"Which best describes the availability of computers for use in your class?

The possible responses are:
a) Not available
b) Available in a lab or library, but difficult to access
c) Readily available in a lab or library
d) One computer available in the classroom
e) Several computers available in the classroom.

Appendix C:

Exact Text of Questions on Computer Use: 1998 NAEP Writing Assessment[6]

Student Reports of Frequency and Type of Computer Use

There are four questions on the Student Questionnaire about computer use. The first asks about general use of computers at home for schoolwork (not necessarily related to writing). The question is:

"How often do you use a computer at home for schoolwork?"

The possible responses are:
a) There is no computer at home
b) Never or hardly ever
c) Once or twice a month
d) Once or twice a week
e) Almost ever day

The last three questions relate to computer use for classwork (not necessarily an English or writing class). The general question is:

"How often do you do each of the following for your classes on a computer?"

The three activities related to writing instruction are:
1. *"Do spelling, punctuation, or grammar exercises"*
2. *"Write in a log or journal"*
3. *"Write drafts or final versions of stories or reports."*

The possible responses are:
a) Almost every day
b) Once or twice a week
c) Once or twice a month
d) Never or hardly never

[6] Student reports are available for all three grades (4, 8, and 12), but teacher reports are available only for grades 4 and 8.

Teacher Reports of Type of Computer Use

In addition, the teacher questionnaire has one question related to computer use in some way. The question is:

"How often do you ask students in this class to do each of the following on a computer?"

Two of the three activities are related to writing instruction:

- *"Do spelling, punctuation, or grammar exercises"*
- *"Write drafts or final versions of stories or reports"*

The third activity was more closely related to reading instruction:

"Read stories or do work related to reading instruction."

The possible responses are:
a) Almost every day
b) Once or twice a week
c) Once or twice a month
d) Never or hardly never

Teacher Reports of Access to Computers

The question is:

"Which best describes the availability of computers for use in your class?

The possible responses are:
a) Not available
b) Available in a lab or library, but difficult to access
c) Readily available in a lab or library
d) One computer available in the classroom
e) Several computers available in the classroom.