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ABSTRACT

This report reviews student usage of microcomputers in schools and the effects of microcomputer use on their academic achievement. Data was collected using: (1) a national survey from the 1989 international "CompEd" survey of the International Association for the Evaluation of Educational Achievement; (2) a 1989 survey of teacher attitudes conducted at Bank Street College; and (3) a 2-year experiment on the use of computer assisted instruction in mathematics. It is noted that, although a wide variety of computer software is currently in use, it is used predominantly to support traditional teaching styles and in teaching word processing and programming. It is concluded that although computer availability is important, the most important factors determining whether teachers use computers effectively are planning time and teacher attitudes, style, and background. Data are presented in narrative and tabular format. (10 figures and 6 references) (DB)

When Powerful Tools Meet Conventional Beliefs and Institutional Constraints: National Survey Findings on Computer Use by American Teachers

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The Center

The mission of the Center for Research on Elementary and Middle Schools is to produce useful knowledge about how elementary and middle schools can foster growth in students' learning and development, to develop and evaluate practical methods for improving the effectiveness of elementary and middle schools based on existing and new research findings, and to develop and evaluate specific strategies to help schools implement effective research-based school and classroom practices.

The Center conducts its research in three program areas: (1) Elementary Schools, (2) Middle Schools, and (3) School Improvement.

The Elementary School Program

This program works from a strong existing research base to develop, evaluate, and disseminate effective elementary school and classroom practices; synthesizes current knowledge; and analyzes survey and descriptive data to expand the knowledge base in effective elementary education.

The Middle School Program

This program's research links current knowledge about early adolescence as a stage of human development to school organization and classroom policies and practices for effective middle schools. The major task is to establish a research base to identify specific problem areas and promising practices in middle schools that will contribute to effective policy decisions and the development of effective school and classroom practices.

School Improvement Program

This program focuses on improving the organizational performance of schools in adopting and adapting innovations and developing school capacity for change.

This report uses national survey data and other information sources to examine what types of computer programs students are using in schools, how much time they spend in computer learning activities, and how their use of computers affects their academic performance.

Abstract

This report reviews student computer use in schools and its effects on their academic performance, using (1) national survey data from the international "CompEd" survey of the International Association for the Evaluation of Educational Achievement, (2) a survey of reputationally expert computer-using teachers conducted at Bank Street College, and (3) a two-year experiment on the use of computers in mathematics instruction. The review concludes that although computer availability is important, the most important factors that determine whether teachers use computers effectively to improve student learning are time and teacher attitudes, style, and background.

In the first several years after microcomputers began arriving in schools, it took a lot of work to create significant learning activities based on their use. To begin with, classes of 25 to 35 students typically only had one or two computers available. And the software that was present usually consisted only of the BASIC interpreter that came with the computer and a range of drill-and-practice exercises in arithmetic and language arts mechanics that essentially duplicated the worksheet activities that occupied too much of students' time as it was. There were "dreams" about computer-using students--dreams of voice-communicating, intelligent human tutors, dreams of desktop electronic information libraries with rapid access to thousands of volumes, dreams of realistic scientific simulations, dreams of young adolescent problem-solvers adept at general-purpose programming languages--but alongside these dreams was the truth that computers played a minimal role in real schools (Becker, 1982).

As we enter the 1990's, it is important to understand how much of that early limited reality still remains, and to understand how much of the idea of transforming teaching and learning through computers remains plausible. We need to assess what needs to be done--and by whom--to attain an intellectually rich school life that integrally incorporates technology. We need to be aware of the "old habits" and "conventional beliefs" that are common among practicing educators and the "institutional constraints" that impede even the best of intentions to improve schooling through technology.

To do this, it is helpful first to examine some facts about computer use in American schools today: (1) what kinds of computer experiences students are having--that is, what types of programs they are using and how much of their learning activity is spent at computers--and (2) how the use of those programs has been shown to affect students' academic performance. The facts that I am most familiar with come from a national survey that I was responsible for: the U.S. administration of the 1989 international "CompEd" survey of the I.E.A. (International

Association for the Evaluation of Educational Achievement) (Becker, 1990a). In addition, I will refer to two other recent studies: a 1989 survey of reputationally expert computer-using teachers conducted at Bank Street College (Sheingold and Hadley, 1990) and another of my own studies: a two-year field experiment on the use of computers for mathematics instruction in grades 5 through 8 in 31 schools around the United States (Becker, 1990b).

The U.S. part of the international Comped survey obtained reports from about 3,000 teachers (of whom about two-thirds were computer-using teachers), as well as more than 1,200 school-level computer coordinators and 1,200 principals. Our respondents constituted a 91% completion rate from a systematic national probability sample of schools and teachers of mathematics, English, science, and computer education in grades 3 through 12. Here are some things we have learned from this survey:

In spite of the growing numbers of computers in American schools (high schools in 1989 typically had between 40 and 50 computers and the median elementary school had nearly 20), older architecture microcomputers dominate in both the installed base and the intended acquisitions (as of 1989). Apple II computers and other 8-bit computers constituted nearly 90% of elementary school computers in 1989 and roughly three-fifths of high school computers. Moreover, at the elementary school level, school-level computer coordinators expected that most computers acquired in the coming months would be Apple II's of one variety or another. Only at the high school level were new computers expected to be primarily MS-DOS or Macintosh computers. And even at the high school level, if schools continue to acquire computers in the numbers that have prevailed fairly consistently for the past 6 years, it will be the fall of 1992 before 16-bit computers constitute a substantial majority of all high school computers

A similar stability holds in the attitudes of computer-using teachers. School-based computer coordinators, as a group, do not see major qualitative changes coming in their need for or use of computers. Figure 1 shows the priorities expressed by these survey respondents for computer-related expenditures. They do express a desire for a greater variety of instructional and general application software. But they also have a higher priority for merely acquiring more computers rather than specifically acquiring computers that are either (a) more powerful or (b) networked. Also, their guesses about what kinds of computer use will increase most in the next two years match almost exactly the major current uses of computers in schools today--in elementary schools, keyboarding and word processing and practice of math and English "skills"; and in high schools, computer literacy education, specifically for teaching word processing, database, and spreadsheet skills, with only minor attention to regular use in math, English, and business education. (See Figures 2 and 3 for estimates of the current distribution of computer use and Figures 4 and 5 for expected increases.) Only a relatively few respondents saw major increases in computer activity coming in such areas as information retrieval and data analysis for social studies and science classes, creative work in art and music, or practice in foreign languages. Overall, the perspective of these school-based computer-using teachers is one of more incremental improvements in current practices that use computers rather than major changes in how they are used.

Of course, the predictions of teachers may not be correct. During the 1980's, some changes certainly did occur in the software that teachers and students used for teaching and learning, and many of these changes may not have been predicted by computer-using teachers early in the decade. The most significant change evidenced in successive national surveys from 1983, 1985, and 1989 is that word processing and keyboard skills have replaced programming as the most common elements in computer education classes and units. However, in addition, the variety of software used by teachers' classes in traditional academic subjects has increased substantially. Not only are more substantive topics "covered" by tutorial and drill software, but approaches to using computers have expanded to incorporate elaborate simulations, games and puzzles requiring reasoning and information gathering, and a variety of subject-specific tools such as mathematical toolkits, outlining and other pre-writing activities, and microcomputer-based science laboratories.

In spite of this increased variety of available software, though, the pattern of software use in typical subject-matter classes remains fairly traditional. The largest portion of instructional software in use today (that is, programs with instructional content rather than content-free computer tools) remains focused on recall of facts and algorithms rather than providing a learning environment for motivating higher-order thinking, problem-solving, and deep understanding. Very little software provides sophisticated assessment of student comprehension and truly individualized feedback to the level of sophistication of even a mediocre teacher. Moreover, most occasions on which students use "tool-oriented" applications such as database, spreadsheet, and word processing programs occur in computer education classes--not as part of instruction in mathematics, science, social studies, or English. Figure 6 provides a representative sample of programs named by individual teachers as the software programs or series that they had used most during the school year, listed according to the level and subject of the classes they taught.

Part of the reason for the relatively limited perspective of many computer-using teachers about what they can accomplish using computers is that in fact only a small proportion of instructional activities of students in most classes of computer-using teachers actually involves using computers. Only a minority of secondary subject-matter teachers who use computers use them throughout the year. Some use computers intensively for only an occasional unit; many others, particularly in science, use computers only occasionally during the year. (See Figure 7, which shows both computer-using and non-using teachers in each bar-chart.) At the elementary level, most computer-using teachers report using computers throughout the school year, but at that level teachers typically have access to only a few computers at a time. (Figure 8 shows that a majority of elementary school computer-using teachers have only one or two computers available for their class.) The relatively infrequent occasions on which computers are used at the secondary level (even by computer-using teachers) and the paucity of computer stations in elementary school classrooms and laboratories means that for most classes in most subjects, computers are not yet the major medium through which students accomplish any of their tasks. Figures 9 and 10 show, for example, the fraction of time that students in an average computer-using class (secondary science classes in Figure 9 and secondary English classes in Figure 10) use computers to accomplish such tasks as "studying scientific facts," "making graphs," or "writing a paper." In all cases, computers are used only a minority of the time, on average. For most activities, computers are used less than one-fourth of the time that any given task is performed. Thus, computers in most subject-matter classes serve primarily as enrichment (reward, motivational diversion, to provide a different perspective) or for occasional individual remediation rather than as a major way that students learn to think and accomplish learning and understanding in that subject.

These statistics, of course, represent averages--meaning that the relatively rare computer-using teachers and classes that use computers in innovative and highly intellectual ways are lost among the more typical traditional computer-using classes. Sheingold and Hadley, from Bank Street, studied a more selective sample of reputationally expert computer-using teachers and show a more differentiated and productive use of computers by that more selective teaching population. That study reported on about 600 teachers from grades 4 through 12, a 50% response rate from a population of teachers nominated by vendors, professional organizations, and state and local technology directors as teachers who are "experienced and accomplished at integrating computers into their teaching." To understand the potential of computers in the hands of expert teachers, Sheingold and Hadley's report provides a useful perspective. However, it is difficult to know how likely it is that their respondents' approach to computer use--incorporating substantial use of productivity tools (e.g., charting and graphing, spelling checkers, painting and drawing programs), Logo and other programming languages, public electronic bulletin boards, and simulations and microworlds--can be easily extended to more typical teachers and their classrooms. The reputationally expert teachers do have more computer experience, having used computers for roughly twice as long, on average, than the subject-matter teachers from the U.S. national survey. And their schools have more than twice the number of computers as is typical in U.S. schools. Is it merely a matter that these expert teachers have more experience with computers or that their schools have more computers, or that they have access to a greater variety of software or to contacts with networks of other computer-expert teachers? Or are there more ingrained and philosophical differences between the teaching styles and approaches of reputationally expert teachers and more typical computer-using teachers?

A field experiment that I conducted in the area of middle grade mathematics suggests that the latter may be true--or at least that merely providing more resources to teachers will guarantee neither more sophisticated use of computers nor particularly successful student achievement outcomes. In that study, I obtained the cooperation of 47 teachers in 31 schools spread across 16 states who were able to provide substantial computer-based learning activity to one of their classes -- with access to at least one computer for every two students, where students used computers for at least an hour per week in mathematics every week during the school year (although some classes fell below that target), and where a comparison class, taught in most cases by the same teacher, composed of similarly achieving students (often by random assignment between the two classes), used only "traditional" media throughout a full school year. The specific software used by teachers participating in the study was selected locally and varied from site to site. In most cases, the software most often in use was computational drill, game-like drills, exercises with some "tutorial" instruction on math concepts or computational algorithms, or abstract games and logic puzzles. Most sites used software loaded on individual disks into independent computers; only one site involving four pairs of classes employed an "integrated learning system" providing an individualized curriculum sequence and automatic placement and management from a single vendor.

On five different mathematics achievement outcomes ranging from standardized tests of computation and applications to researcher-developed measures of estimation and mental arithmetic, there were only negligible differences between students having substantial practice using computer software and those given only a "traditional" math course. The one site with the individualized "integrated learning system" had the best results, but use of no other software package was associated with results markedly different from the average. Classes of the youngest grade level studied (grade 5) had generally positive results, while the higher grade levels (7 and 8) more often had negative effects than positive ones. Effects were generally positive for sites with primarily students from primarily working-class backgrounds, particularly those with some students from minority backgrounds (few sites were predominantly minority), but effects were more often negative for sites with large numbers of students with middle- or higher- social class backgrounds.

These results suggest to me that traditional mathematics learning that involves fairly traditional software, even when used substantially throughout the year has generally beneficial consequences only in certain circumstances--that overall such an approach may even be "harmful" as often as it is "helpful." But the larger effort to conduct the field research itself also had a lesson: namely that teachers and schools that provide students with substantial computer experiences will implement a fairly traditional program of instruction that will not be greatly different from the curriculum that the students would have followed without the computers.

For computers to make a difference in how students experience schooling will require teachers and administrators to modify their concepts of appropriate and inappropriate teaching behaviors, to reprioritize the value of different types of instructional content, and to change habits and assumptions that guide their classroom and school management strategies. Computers and computer software may be a possible vehicle or model for providing curricular enhancement for teachers and students to use, but merely by their availability or even by their presence computers will not assure (nor even make substantially more likely) that changes in education will occur.

The way that teachers teach is a product of their own schooling, their training, and their experiences as teachers. Each teacher's teaching style is also influenced by personal factors in their background (their personality and their belief system). But all teachers' styles are also influenced by regularities in the social structure in which most of them work. For example, the fact that teachers are responsible for directing the efforts of 25 to 35 similarly aged, but differentially developing, children or adolescents means that purely psychological models of motivating and tutoring individual children may be only loosely relevant to the task that teachers face. That is why programs that orchestrate thorough-going individualization of instruction ("to meet each child's own needs") almost uniformly have gone through a cycle of enthusiasm, expansion, disappointment, and rejection. As analysts have found, "the reformers...make unwarranted assumptions about students' capabilities for independent goal setting and learning or produce individualized curriculum materials that are focused too much on low-level isolated skills and involve too much testing or other managerial complexities" (Good and Brophy, 1987).

The circumstances of teaching also intervene to affect teachers' proximate goals in ways that often distort their more conscious long-range goals. For example, although teachers may profess valuing independent student accomplishment and successful collaboration among student peers, statistical records of classroom behavior typically report that the largest proportion of time is spent with students working at their own desks on narrowly defined worksheet tasks or listening en masse to the pronouncements of their teacher (e.g., Goodlad, 1984). Why is this the case? Because behavioral control is seen by teachers as their biggest problem (Goodlad, 1984), and because teacher-centered whole-class lessons and workbook-centered individual activity is most conducive to quiet order in the classroom.

For several years, schools and teachers have had available a wide range of software that could bring major changes to what students do in classrooms and what they learn. There are software and communication systems for students in schools widely scattered around the country to cooperatively work on investigative and writing tasks (e.g., AT & T Learning Circles; National Geographic Kidsnet). There are simulated systems or "microworlds" such as Robot Odyssey, mathematical tools such as the Geometric Supposer series, structured laboratory activities involving real-world data collection such as Science ToolKit, and more content-free environments such as those created using the Logo programming language for students to construct meaning and thereby more deeply understand systems of logic and content. And of course, "adult-world" spreadsheets and database software that can be adapted to inquiry approaches in social studies, science, and other secondary school subjects. This software is widely available. But it constitutes only a minute portion of computer use in regular school subject classes.

The next generation of computers and computer-linked information technology will make possible an even broader range of computer-based activities for classes. Interactive videodisks and multimedia software are a particularly "hot topic" now. Perhaps less glamorous but with as much educational potential are CD-ROMS filled with sophisticatedly indexed multi-volume encyclopedias, books, and atlases. Several of these reference tools, containing combinations of encyclopedias, pronouncing dictionaries, and point and zoom atlases, are now on the market and available to teachers--with the right computer hardware, of course. Thus, schools and their students will shortly have access to vast quantities of information in easily used and highly visual formats. However, by themselves these technologies will give students neither the motivation to explore these new resources nor an intellectual structure that organizes their search. Someone must provide those essential ingredients--software developers, school system curriculum developers, or teachers--someone must organize how all of these resources are to be used.

But for most teachers, the time required to plan even modest variations to the routine of direct instruction of specific facts and student practice of skills is hardly present. Both the representative national survey and the survey of reputational experts found teachers saying that the biggest impediment to better computer use is the lack of time required to figure out how to use computers well. The more complex the software and the more it offers student-centered discovery learning approaches, the more difficult teachers will find the task of getting some constructive benefits from its use--even if the potential for student accomplishment is that much greater.

Nor should we assume that school districts or software developers will find the time to orchestrate, model, and validate effective curricular use of powerful software. Districts are under increasing pressure to trim central office bureaucracies in order to make schooling more efficiently managed and to relocate decision-making to the building level. Nor can we expect software producers to do all that is necessary. The more creative and intellect-empowering software generally is accompanied by more costly investment in software development, and producers are strained to dilute their efforts by providing systematic lesson plans in addition to the software; they seek to get their products to market and begin to recoup their investments in the competitive marketplace.

So, yes it is clear that the microcomputer and communications revolution has the potential of providing a great range of powerful and enabling tools for use by children, adolescents, and teachers in the context of group-based and individual instruction. But it is not clear that most of this potential will be reached. Societal investment in the education of children is--and always has been--a marginal enterprise, often just enough to keep students off the streets and reasonably quiet and just successful enough to produce basic reading literacy and a modicum of civility and cultural knowledge in most of their charges before they are released to the world. The challenge for those in education is to work within these severe constraints to adapt schooling to the opportunities presented by technology in ways that are effective. Better software and more powerful hardware are only a small part of a technology-assisted improvement in schooling. By far the greatest necessity to "win this war" is for teachers, curriculum developers, and software producers all to make a commitment to create, polish, and disseminate effective ways of using computers in classroom environments. And researchers like myself must be prepared to take the results of that effort and determine in a fair and unbiased way under what conditions those goals have been attained.

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Figure 1

Priorities for Computer-Related Expenditures (Percent indicating "important" or "very important")

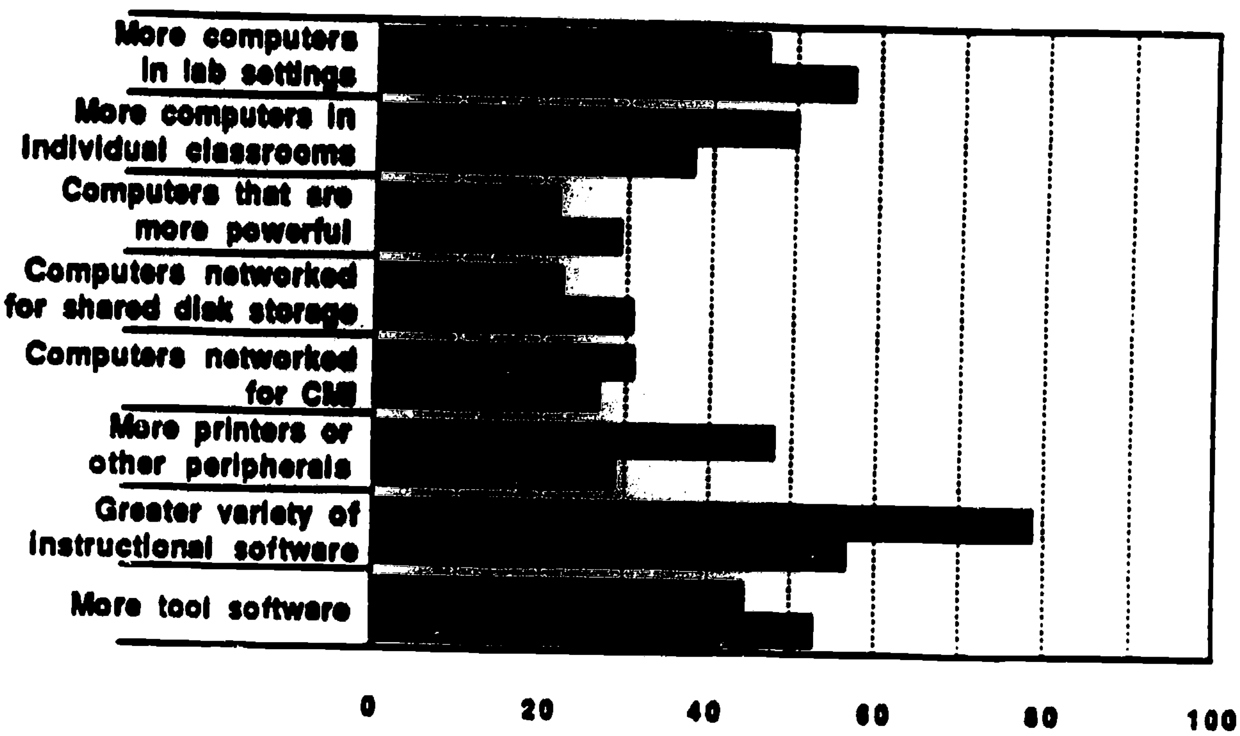

Figure 2

Percent of All Computer Use, High Schools

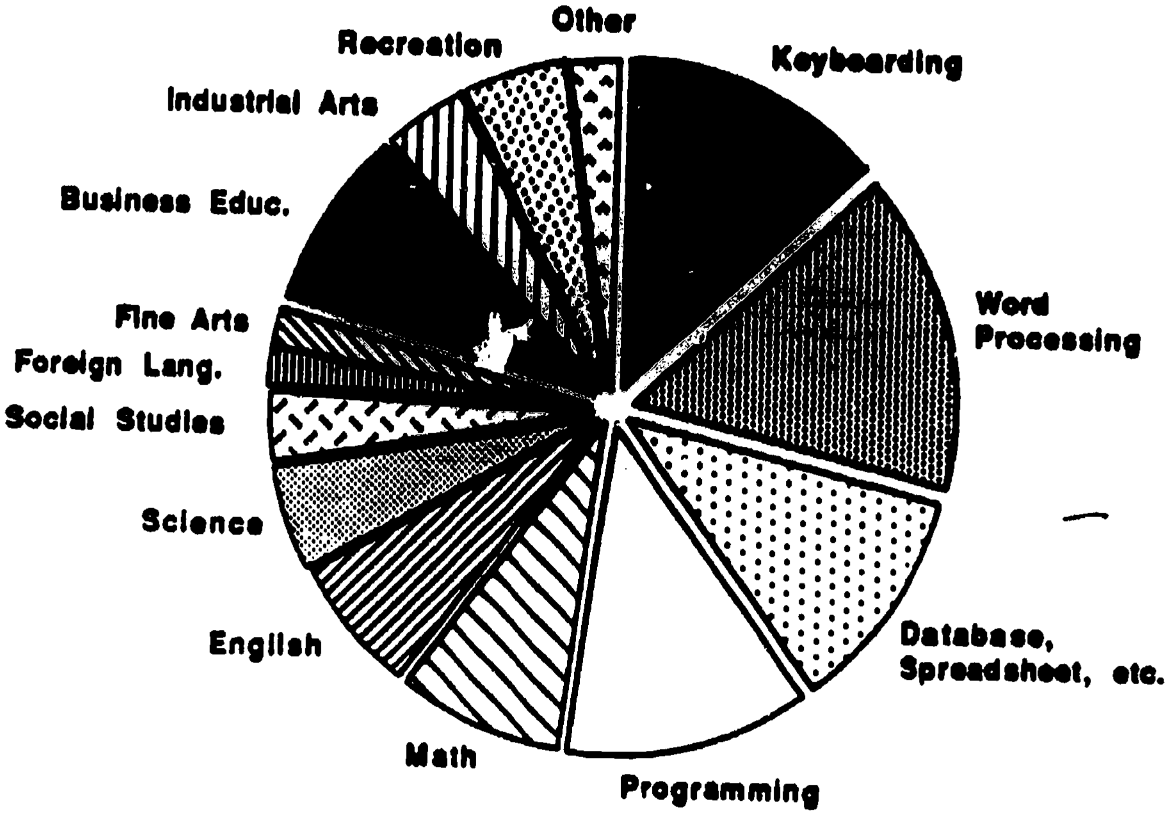

Figure 3

Percent of All Computer Use, K-6 Elementary Schools

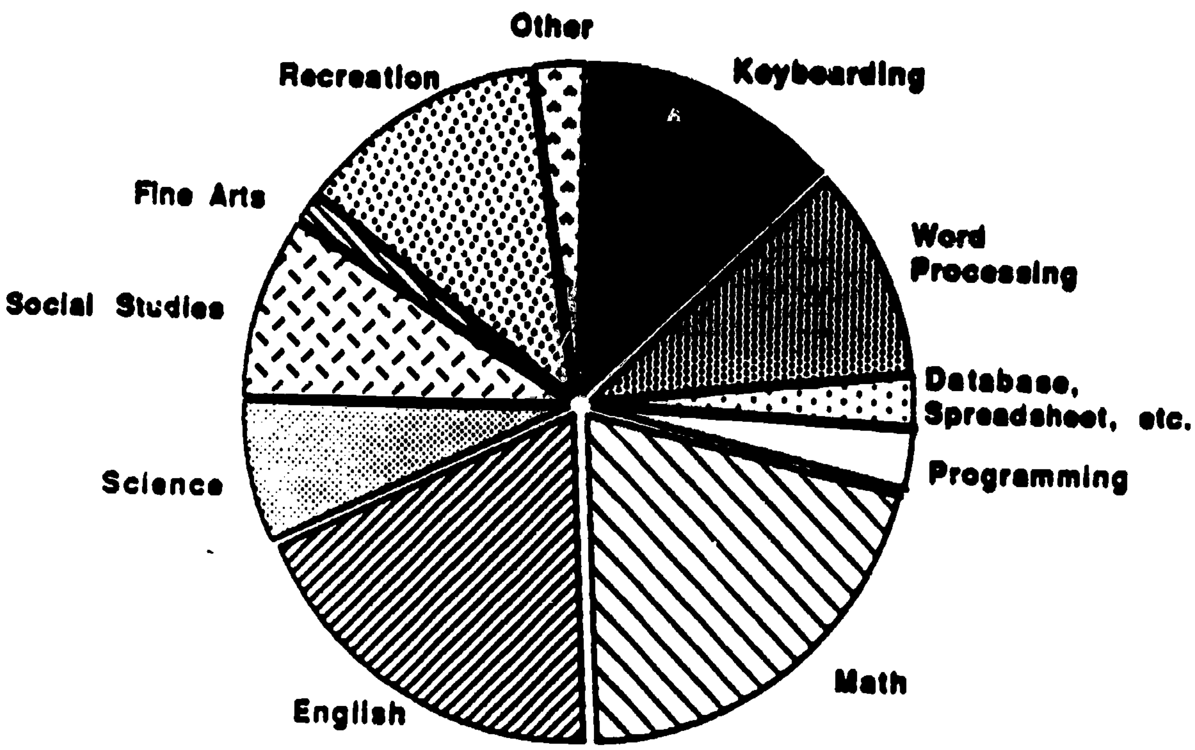

Figure 4

Expected Greatest Increase in Computer Use (Next Year or Two) HIGH SCHOOLS

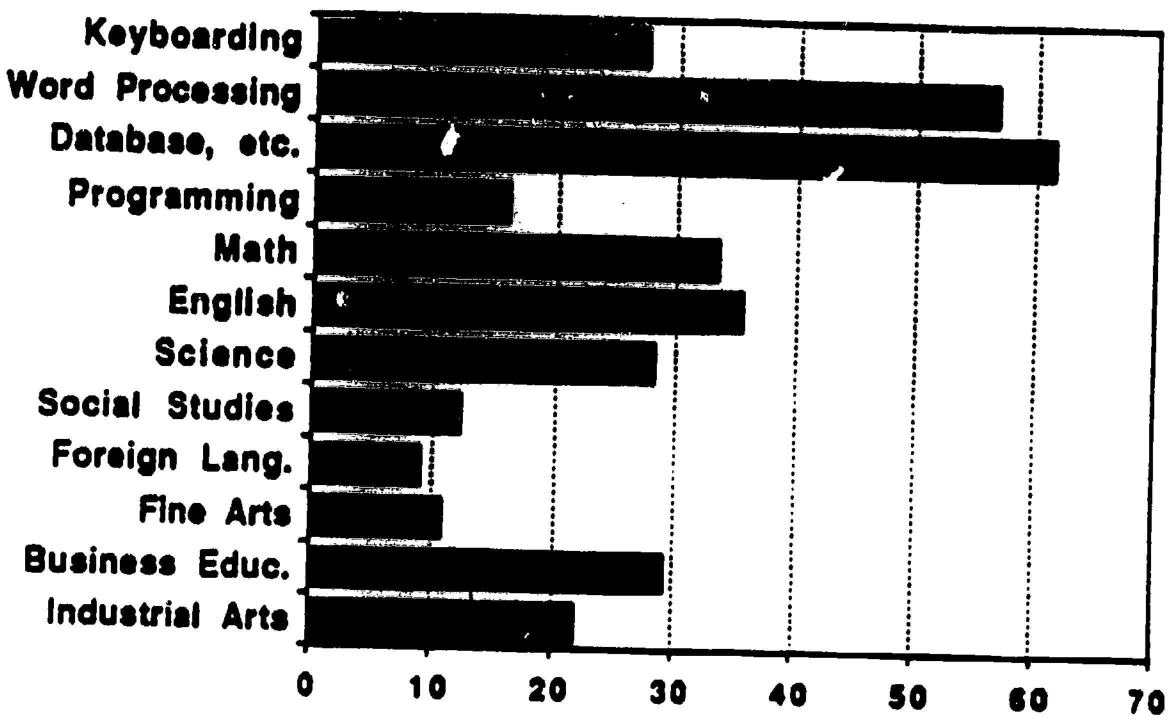

Figure 5

Expected Greatest Increase in Computer Use (Next Year or Two) K-6 ELEMENTARY SCHOOLS

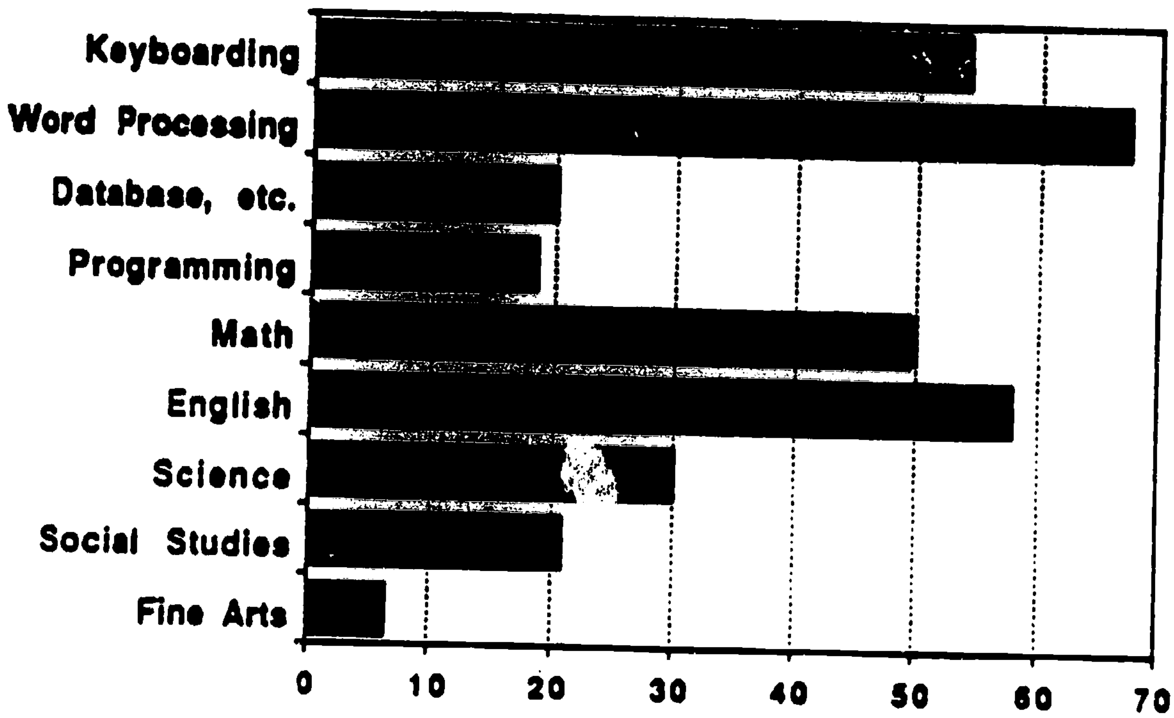

Figure 6: Representative Software Used In American Schools

ELEMENTARY

Alligator Mix
Carmen Sandiego
Clock Math
Fred Writer
Grammar Examiner
Kid Writer
Math Blaster
Micro Workshop
Number Muncher
Oregon Trail
Reading Comprehension
Print Shop
States & Capitals

MIDDLE-MATH

Bumble Graph
Conquering Fractions
Decimal Dungeon
Fraction Munchers
In Search of the Secret Stone
LogoWriter
Math Blaster
MECC
Whole Numbers

MIDDLE-SCIENCE

Appleworks
Bank St. Filer
CAI on the Ear
Discovery Lab
Hubble Space Tele.
MECC
Operation Frog
Square Pairs (Science Vocab.)
Sumeria

MIDDLE-ENGLISH

For content:
CCC Reading
Diascriptive Rdg
WICAT -- Editing
Word Attack
Word Munchers

For writing:
Appleworks (2)
Bank St. Writer
Easy Working Writer
Fred Writer

COMPUTER ED
(besides languages)

ELEM:
Math Blaster
MECC Keyboarding
Mouse Paint
Reader Rabbit
World of PAWS

MIDDLE:
Bank St. Writer
Fred Writer
Multiscribe
Oregon Trail
Print Shop

H.S.
Appleworks
PFS First Choice
Green Globs
Quattro
Word Pro 3

H.S. MATH

Algeblaster
CCC Math
Conduit: Discovery
Green Globs
Mastering SAT
MCP-Algebra II
Omnifarous Plotter
Sunburst

H.S. SCIENCE

Basic Electricity
Biology Programs
Cell Respiration
Focus Media Chemistry
Matter and Energy
McMillan Chemistry
Physics S.W. (J&S)
Vernier Graphical Analysis

H.S. ENGLISH

For content:
Close Plus
Diascriptive Reading
Hartley Adjectives
MECC Reading Machines

Wheel of Fortune

For writing:
Appleworks (3)
Microsoft Word
PFS Write

Figure 7

Extent of Use by Teacher's Classes

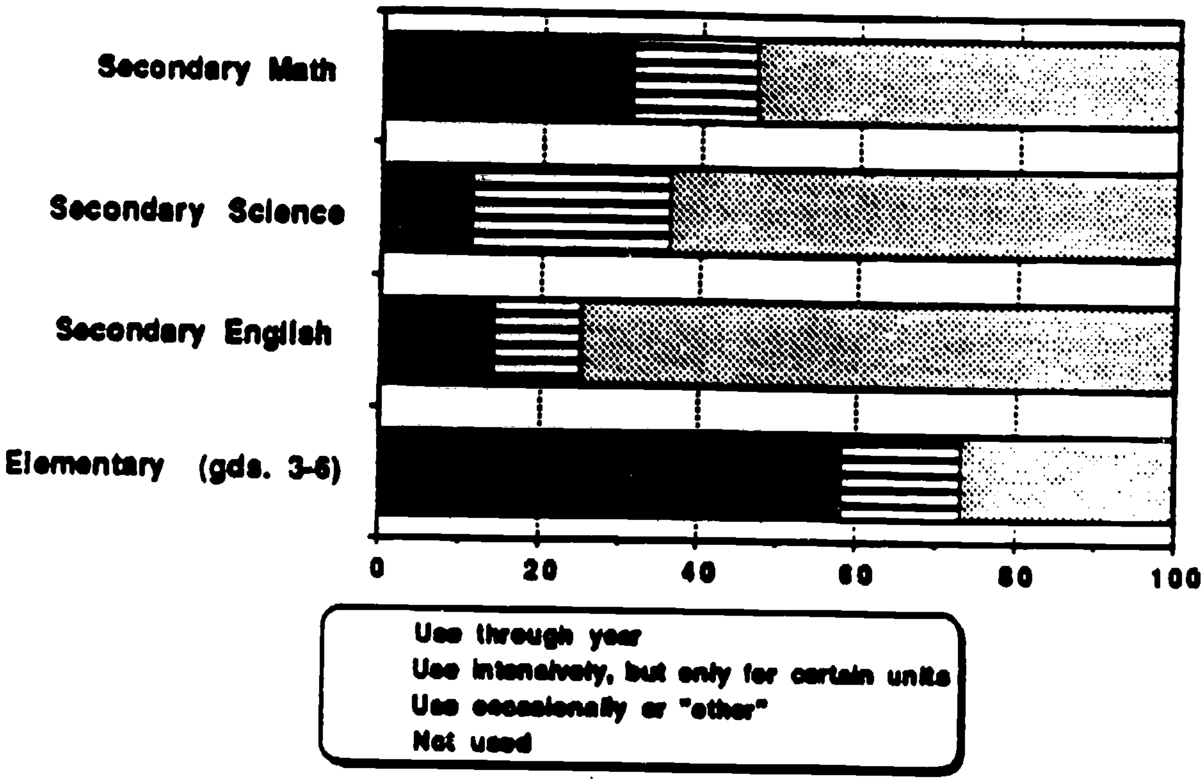

Figure 8

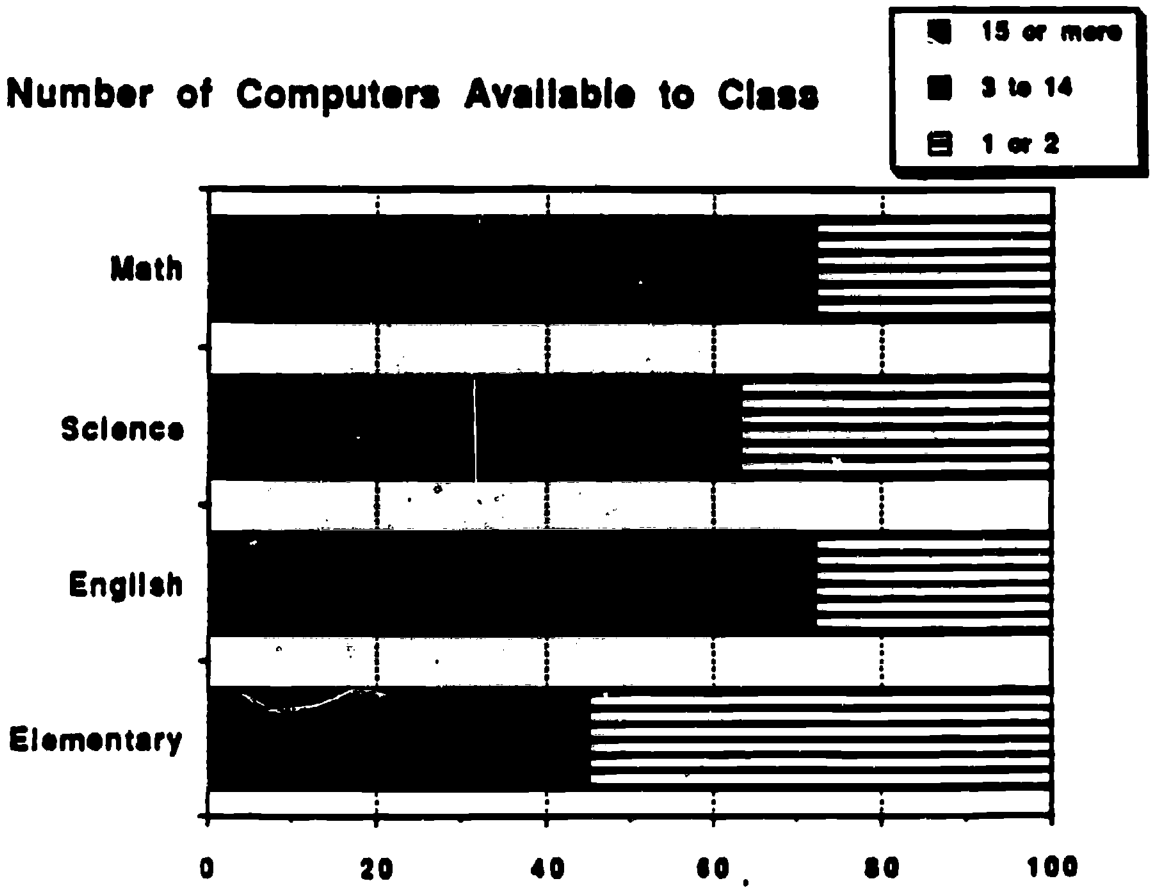
Number of Computers Available to Class
15 or more
3 to 14
1 or 2
Math
Science
English
Elementary
0
20
40
60
80
100

Figure 9

Computer-Using Science Teachers (Secondary)

Mean Percent of Time That Students Used Computers for Specified Assignment

Teacher Gave This Assignment — Students Used Computers

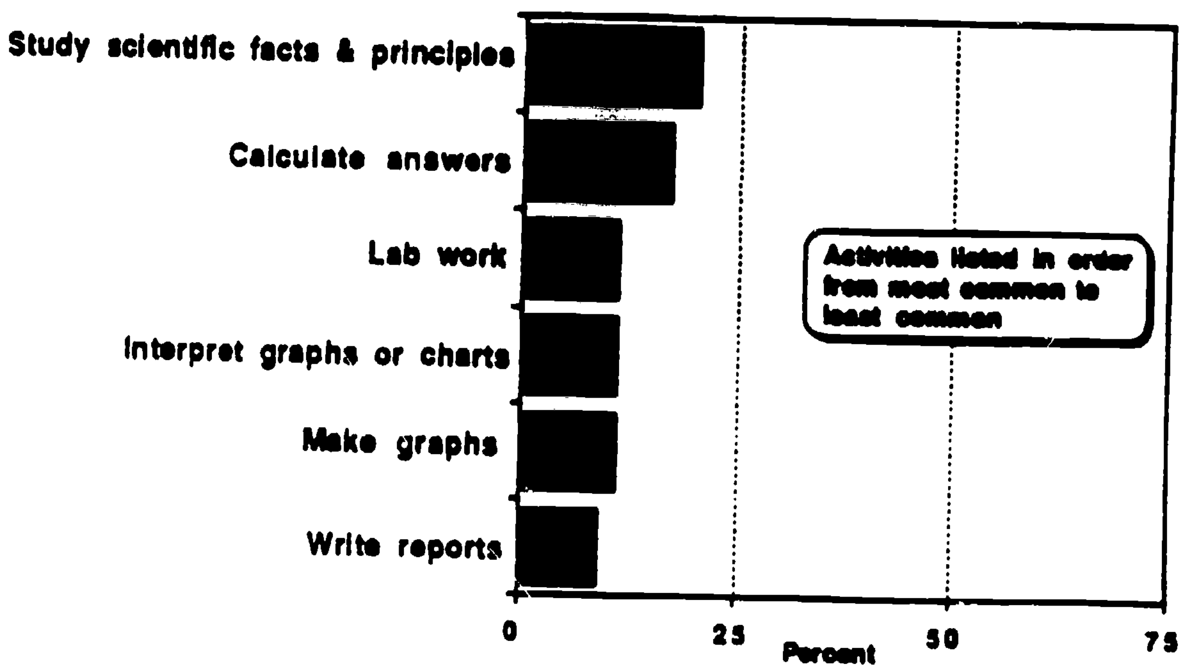

Figure 10

Computer-Using English Teachers (Secondary)

Mean Percent of Time That Students Used Computers for Specified Assignment