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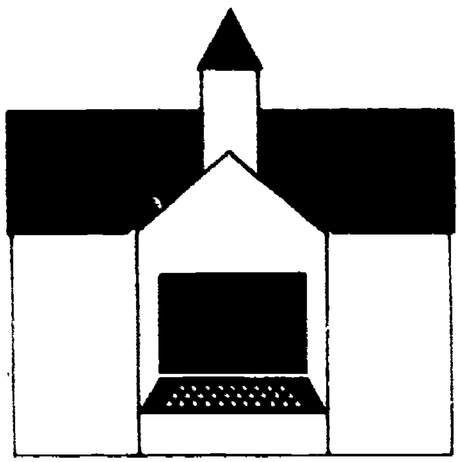
ABSTRACT

This report summarizes the results of a national survey of U.S. elementary and secondary schools, conducted during the 1982-83 school year, which focused on the schools' instructional use of microcomputers, including use both as a means of instruction and as an object of instruction. Specific topic areas covered include: the number of microcomputers in the schools; major microcomputer uses; number of student users; access time per student; junior high, middle school, and low income elementary school use patterns; areas of microcomputer impact as viewed by computer-using teachers; physical location of microcomputers in the schools and locational impact on use patterns; acquisition and use patterns; student grouping for microcomputer use and teacher management of waiting time; and interpretative remarks focusing on research needs and collaborative research efforts of researchers and educators. (MBR)

HOW SCHOOLS USE MICROCOMPUTERS

Summary of the First National Survey



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March, 1985

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Table of Contents

Introduction

During the last several years, American schools have spent a large portion of their limited discretionary funds on the purchase of general–purpose microcomputers and associated instructional materials. These expenditures have been made in the expectation that the computer––either as an instructional tool or as an object of instruction––will soon become an essential ingredient of pre–college educational practice, and that now is the time to begin learning how to function with this new medium.

Yet no tool will be valuable if it cannot be used within the pre–existing framework of organizational activities. For example, in many cases a child must spend an hour doing "busy work" in order to get a ten–minute turn on a classroom computer––perhaps a turn shared with a "partner." It is possible that the more motivating and more effective instructional time at the computer is offset by a decline in the quality of learning that occurs during the "waiting time," compared to prior instructional practices.

Similarly, because most children pay better attention to a task when supervised by a teacher, and because it is too costly for schools to assign a teacher to supervise fewer than a classroom of students, most schools use their computers less than they would prefer. Sometimes, decisions about who may use the computers are determined, not on the basis of educational need, but on the basis of which students can be trusted to use the computers without supervision.

Using computers well is not merely a matter of finding good software, but of designing a social and instructional system that maximizes the benefits that computers might bring to different types of students facing different educational challenges. It is important to consider what schools have been doing with the computers that they have been acquiring, and what has made some schools more successful than others in using their equipment.

This report is based on a national survey of elementary and secondary schools in the United States, conducted during the 1982–83 school year. The survey focused on the schools' instructional use of microcomputers, including their use as a means of instruction (e.g., drill–and–practice programs for arithmetic instruction) and as an object of instruction (computer literacy units and computer programming courses).

The survey was conducted two years ago, and in that time many schools will have learned a great deal about how to make better use of their computers. However, the results will certainly be valuable for schools that have more recently begun using computers––and who are likely to be confronted with the same kinds of problems that the surveyed schools were facing in 1983. For the more computer–experienced schools for whom this report resembles a portrait of their former "computer youth," the statistical patterns shown here may be a useful benchmark with which they can compare their current performance in using computers.

Method

The survey sample was a scientific sample of 2,209 U.S. elementary and secondary schools selected from all the public, private, and parochial schools in the U.S. Schools most likely to have had experience with computers were "oversampled" in order to obtain the most detail possible about how they were used. However, the statistical analysis compensates for this oversampling so that all reported percentages, averages, and other measures may be interpreted as coming from a completely representative sample of U.S. schools.

The survey forms were completed by principals and by teachers designated by their principal as their school's "primary computer–using teacher"––that is, "the teacher who has used a microcomputer most or who is <u>most knowledgeable</u> about how microcomputers have been used at (their) school by teachers and students." The educational community is indebted to our professional colleagues who took the time and effort to contribute their knowledge and experience and, by doing so, helped to produce this report.

Survey forms for the primary computer-using teacher were completed by 70% of the 1,580 schools in the sample with microcomputers. Two-thirds (727) of the responding teachers were from secondary and middle-schools, and 28% (305) were from elementary schools. The remaining respondents were from schools that covered grades K-12 and are excluded from this particular analysis.

Most of the items used in this analysis come from the computer-using teacher questionnaire, an 18-page document requiring an average of one hour to complete. Teachers completed a table on each microcomputer acquisition, indicating when it occurred, how many computers were involved, and what features the computer had. They provided information about how microcomputers were being used at their schools by teachers and students in general, and they reported specific information about their own teaching practice. They reported the subject-matters and grade levels they were currently teaching; the classes and subjects for which they used microcomputers; and the proportion of time (during their first class of the day) during which computers were in use. They indicated their knowledge and practice of computer programming, their opinions of the value of microcomputers for various subjects of instruction, and their opinions on the extent to which having a microcomputer affected student achievement and other specified outcomes.

They provided data about twelve ways of using microcomputers (e.g., "programming to solve math/science problems," "teacher use for record-keeping"), indicating which were "regular" or "intensive" uses at their school. Also, they completed a table for up to five teachers' use of microcomputers, including how many of each teacher's students used a microcomputer keyboard during an average week, for how many minutes, and in what activity (e.g., "drills," "writing programs").

The Number of Microcomputers in Schools in 1983

At the time of the survey, a majority of schools that had microcomputers had fewer than five of them. Fewer than 10% of the micro-owning schools had as many as 15 microcomputers, enough to serve about half of the students of one classroom at any one time. Although schools have been doubling their stock of microcomputers every year for the past several years, even in 1985 a majority of schools operate with fewer than 10 microcomputers, even though schools typically cluster students in groups of 25 to 30 for instruction.

Secondary schools have been dominating microcomputer use, at least until recently. In 1983, high schools were twice as likely to own a microcomputer as elementary schools, they had nearly four times as many of them (and even considering their larger student bodies, twice as many per student), and they used them for more hours of the week. As a result, out of the total time that microcomputers were used by students in school, about three-quarters was in secondary and middle schools--only one-fourth was in elementary schools.

Elementary schools were also affected by having microcomputers with less capacity. For example, in 1983, 37% of microcomputer-owning elementary schools did not have any disk drives for their microcomputers. This was three times the fraction of micro-owning secondary schools without disk drives. Ten percent of secondary schools with micros had their machines linked in a "network" of some kind, whereas this was true of only 1% of microcomputer-owning elementary schools.

So, two facts dominate our picture of the number of microcomputers in schools in early 1983: First, most schools using microcomputers had many more students in a single classroom than they had computers for the entire school. Second, the number of computers and the student–computer ratios were even less favorable in elementary schools than they were in secondary schools (especially compared to high schools).

The Major Uses of School Microcomputers

Of all the ways in which schools might be using computers to assist in instruction, three ways stood out in the survey results above all others: to provide students with a general introduction to what computers are and how they can be used, to teach rudimentary computer programming skills by using the Basic programming language, and for practicing rote–learned computational and language–arts skills through "drill–and–practice" computer programs.

Table 1

"Regular" or "Intensive" Uses of Micros in Schools

(Percent of Teachers Reporting Such Usage at their School)

ELEMENTARY	PERCENT USING FOR PURPOSE INDICATED	SECONDARY
	85%	Introduction to computers
	76%	Programming instruction
Introduction to computers	64%	
Drill-and-Practice	59%	
Programming instruction	47%	
Tutoring for special students	41%	
	31%	Drill-and-Practice
	29%	Business ed./vocational
	29%	Programming to solve problems
Programming to solve problems	27%	
Recreational games	24%	
	22%	Demonstrations, labs, simulations
Demonstrations, labs, simulations	20%	Tutoring for special students
	19%	Recreational games
	15%	Teacher record-keeping
	14%	Administrative use
Administrative use	10%	Teacher tests, worksheets
Teacher record-keeping	7%	Student papers, word-processing
Teacher tests, worksheets	5%	
Student papers, word-processing	3%	

How Schools Use Microcomputers

Table 1 indicates the proportion of teachers at microcomputer-owning schools who reported "regular" or "intensive" use of microcomputers for each of twelve instructional functions.

Apart from general computer literacy, computer programming was the clearly preferred activity in secondary schools, while "drill-and-practice" led programming as the most employed application of microcomputers in elementary schools.

Microcomputers were also used to assist individual students in elementary schools and in the business programs at high schools, but less frequently than either programming activities at either level or drill activities for more inclusive groups of elementary students. Demonstrations, problem-solving using programming, and recreational games were used regularly in about one-fifth of the schools with microcomputers.

Management activities such as using micros to help produce tests or worksheets, and other student activities such as word-processing, were far down the list, getting mention as a "regular" use in well under 10% of the schools having computers.

In 1983, teaching computer programming nearly everywhere meant instruction using the Basic programming language. Of the schools which provided 30 hours or more of programming instruction to at least a few students (as did a majority of microcomputer-owning schools), 98% taught Basic and 5% each taught using Fortran, Logo, and Pascal. 84% taught programming only in Basic. Preliminary examination of our new 1985 survey suggests that the Logo language has gained a modest foothold in elementary school and middle-school programming instruction, but Basic is still the predominant instructional programming language at all pre-college levels.

The survey asked teachers not only about current uses of microcomputers, but also about uses that had been anticipated at the time the school's first microcomputer was obtained. In addition, some inferences can be made by looking at differences between schools that were in their third year of having a microcomputer and those that were in their second year or their first year. Tables 2 and 3 report these data.

Table 2 shows that among schools that obtained their first microcomputer before July, 1981, about the same number used their microcomputers more than they anticipated for programming instruction as used them less for programming than anticipated. However, this was not the case with drill-and-practice programs. A greater number of schools reported a decline in the use of microcomputers for drill-and-practice than reported an increase over their initial anticipations.

Table 2

Actual Use of Micros Compared to Anticipated Use

(Universe: Schools with a Microcomputer prior to July, 1981)

	Elementary	Secondary
Teaching Programming		
More Use than Anticipated	25%	15%
Same Use as Anticipated	49	74
Less Use than Anticipated	26	11
Use for Drill-and-Practice		
More Use than Anticipated	21%	13%
Same Use as Anticipated	44	53
Less Use than Anticipated	35	34

The longer a school had had a microcomputer, the more it was using computers for teaching programming and the less it was using computers for drill-and-practice. This is true for both elementary schools and secondary schools. (The data are shown in Table 3, which is based on an index of "extent of use" questions in the survey.) Even among elementary schools, which as a group used computers for drill-and-practice more than for programming, those that obtained their first microcomputer prior to July, 1981 used their micros more at the time of the survey to teach computer programming than to teach traditional math and language subjects by computer-based practice.

Table 3

Current Use of Micros by Year First Obtained Micro

(Scores are index values from several responses.)

	Elementary	Secondary
Teaching Programming		
Schools in First Year	18	38
Schools in Second Year	24	46
Schools in Third Year +	46	64
Use for Drill-and-Practice		
Schools in First Year	38	27
Schools in Second Year	32	17
Schools in Third Year +	33	14

Two inferences from these results are possible. After having tried both drill and programming uses, secondary schools and even elementary schools may have found it more useful to employ these machines to expand the curriculum--teaching students about computers and how to program them--than to provide another means to teach traditional subject-matter. Alternatively, it may be that the "pioneer" schools became disenchanted with the drill-and-practice software available at the time and did not venture back to examine more recent software products which schools that more recently became microcomputer owners were trying to use.

How Much are Micros Actually Used

The fact that microcomputers are now present in more than two-thirds of U.S. schools does not necessarily mean that most students are getting exposure to them nor that they are being intensively used. A handful of microcomputers available to student bodies of many hundreds or even thousands means either that students must get very little time to experience microcomputers or that only a few students may get sufficient time for the experience to be more than merely exposure to a new cultural object.

Number of Student Users. Respondents to the survey reported student use for each of up to five computer-using teachers. Based on these answers and imputing additional use to other teacher-users, about 70 students used microcomputers in the typical micro-owning school during any given week in early 1983 (62 in elementary schools and 77 in secondary schools). This represents about one student in every seven in those schools having a microcomputer.

Elementary schools were more likely than secondary schools to have obtained a microcomputer but not yet begun to use it with students; but they were also more likely to give a substantial fraction of their students some exposure to the computer. In about a third of the micro-owning elementary schools, more than 40% of the students had some contact with a micro; this was true for only one out of every eight secondary schools with computers.

Access Time Per Student User. On the average, microcomputers in the schools surveyed in 1983 were used by students for about two to three hours per day. (The typical elementary school micro was used 11 hours per week; the typical secondary school micro was used 13 hours per week.) Because micro-using elementary schools typically owned only two microcomputers in 1983, it would have been difficult for students to receive a much exposure.

Table 4 shows that a third of the elementary school student–users during a given week actually used a micro for 15 minutes or less that week––equal to three minutes per day. (The survey did not inquire whether the same students used the microcomputer each week, or whether different students got the 15 minutes of exposure during different weeks.)

Table 4

Weekly Computer Time Per Student User

(Universe: Schools Reporting Student Use on Teacher-by-Teacher basis)

Of those students WHO DO use a micro, how many students use one...	Elementary	Secondary
No more than 15 minutes per week	31%	21%
16 to 30 minutes per week	45%	15%
31 to 60 minutes per week	22%	27%
More than 1 hour per week	2%	37%
Median number of minutes per week	23 minutes	45 minutes

Most of the remaining computer–using students got only an additional ten or fifteen minutes exposure per week. Only one student user in 50, at the elementary school level, had more than one hour of time on a microcomputer during a given week––that is, about 15 minutes per day, each day for a full week.

Secondary schools typically had two to three times as many micros as elementary schools. However, secondary schools used their micros with about the same number of students as elementary schools, even though they tended to be about twice as large. Consequently, secondary school students who did use microcomputers had an opportunity to use them for longer periods of time.

As Table 4 shows, nearly four out of every ten secondary school microcomputer users had access for more than one hour during the week that they were a "user." On the average, secondary school students who used a microcomputer had twice as much access during an average week as their elementary school counterparts. (High school students used a computer 3 times as long as fourth graders.)

Schools with more microcomputer resources can do two things with their relative surplus: (1) extend access to more students or (2) give each student–user a more intensive computer experience. Elementary and secondary schools display striking counter–tendencies regarding these alternatives.

Elementary schools with more micros did not give students any more minutes per week at the computer keyboard––they just extended the opportunity to a larger number of students. At the secondary school level, the relationships were exactly reversed. The more micros a school had, the more minutes per student user, but there was no relationship between the number of micros and the percent of students who were users.

As noted earlier, elementary school teachers indicated that a major function of their school's computers was for drills––a means of improving student achievement in basic math and language arts skills. However, given the rather limited exposure of elementary school students to drill–and–practice on the computer, and given that having more computers usually translates at this level into more students gaining access rather than more access time per user, perhaps microcomputers in elementary schools have had more of an impact on the students' knowledge about small computers than on their basic academic skills. Given that the typical elementary "drill–and–practice" user received less than 20 minutes practice time per week, the primary consequence of using these "drill–and–practice" programs may have been to acquaint students with a bit of the nature and capacity of computers in the context of showing them how computers might be useful in practicing skills. It is doubtful that they could have made substantial progress in subject–matter learning in this limited amount of time.

Junior Highs and Middle Schools

The pattern of micro use in junior highs and middle schools seems, on balance, to have been closer to that in elementary schools than in high schools. For example, junior highs (including middle schools) reported that the typical micro user got 30 minutes of access time per week--half as much as the typical high school student user received and not much more than the 24 minutes per week typical of elementary school student users.

Programming instruction, in particular, was much less frequently reported to be an "intensive" use of microcomputers at junior highs and middle-schools (32%) than at high schools (64%), although more junior high/middle-schools concentrated on programming instruction with students than K-6 elementary schools did (18%).

Junior high/middle-school respondents were also somewhat less positive about the effects of microcomputers on their students. They less often reported a major impact on students working independently than the high school respondents did, for example (14% vs. 21%). They were less likely to report that having a micro resulted in "much more" academic learning by "above-average" students (16% vs. 27%), or "much more" learning by average students (4% vs 7%). On the other hand, they were more likely to report "much more" learning by below-average students (12% vs. 5%).

Schools at these middle grades appear to have fallen short of their expectations in computer usage. Based on data not shown in these tables, this group of schools was doing less programming instruction than planned <u>and</u> less drill-and-practice as well. The same is true for elementary schools but to a smaller extent.

Finally, one measure of overall success of the use of computers as an object of instruction is the degree to which students use micros on their free time before school, at lunch, and after school. Our survey shows that microcomputers in senior high schools were used about twice as much during these non-instructional times than those in middle/junior highs or those in elementary schools.

Two Patterns In Low-Income Elementary Schools

The schools in our sample were divided into four socioeconomic status groups based on rough estimates of student family incomes and were divided into those schools whose student bodies were predominantly white and those that were predominantly black, Hispanic, or other minority. At the elementary school level, about 2/3 of the predominantly minority schools were also in the lowest of the four socioeconomic status (SES) groups of schools; also, about 1/3 of the schools in the lowest SES group of schools were predominantly minority.

Despite their rough economic similarity, low SES schools in the sample that were predominantly white had very different patterns of microcomputer use than did the predominantly minority schools. The number of schools for this comparison is rather small--32 predominantly minority elementary schools with micros and 38 low SES predominantly white elementaries--but the differences between these two groups are substantial.

Predominantly minority elementary schools used drill-and-practice activities much more than they used programming activities with their students. In contrast, low SES predominantly white elementary schools did programming with students much more often than they used their micros for drill work--even more than the highest SES elementary schools, which did slightly more programming than drills.

Secondly, predominantly <u>minority</u> elementary schools reported intensive use by <u>below-average</u> students much more often than did other groups of elementary schools, whereas low

SES predominantly white schools stood out in the frequency with which they reported intensive use by above-average students. Table 5 presents the complete tabulations of this data.

Table 5

Race, Socio-Economic Status and Micro Use in Schools

(Universe: Elementary Schools with One or More Microcomputers)

	Predominantly WHITE Elem. Highest SES	Middle SES	Lowest SES	Predomnt. MINORITY Elem.
Median ratio of students per microcomputer	155:1	183:1	192:1	215:1
Median hours per week that students use micros.......	10	13	10	20
Median minutes of use per week per student user.	24	22	35	18
Percent of schools having a "Computerist" teacher...	46%	33%	35%	14%
Percent reporting "intensive use" of micros...				
for drill-and-practice....	13%	18%	9%	33%
for programming instruction	21%	17%	49%	10%
with "Above Average"......	24%	30%	51%	26%
with "Average" Students...	14%	9%	22%	12%
with "Below Average"......	16%	12%	10%	32%

Thirdly, although predominantly minority elementary schools reported using their microcomputers for twice as many hours per week as did low SES white schools, the low SES white schools reported that an average student user got twice as much computer time during the week. Finally, low SES predominantly white elementaries were more likely to have a teacher on their staff personally knowledgeable about computers than were the predominantly minority schools.

Thus, there are clear differences between these two categories of schools---schools which are fairly similar in terms of gross economic characteristics. In minority communities, those elementary schools that did have microcomputers were trying to use their micros to bring up the achievement levels of their lower-performing students. In white communities of relatively less well-off families, schools appeared to prefer to give access to micros primarily to their better-achieving students, providing them with some instruction in computer programming, and then allowing them to work independently, in a more informal and less teacher-directed structure, to master computer skills.

These are two very different approaches to using microcomputers in elementary schools with students from relatively less privileged backgrounds. Although their predominance happens to be associated with student racial characteristics, it has yet to be shown which approach has more merit. Indeed, they merely reflect different assumptions about the appropriate role of today's microcomputer hardware and software.

On the one hand, some schools believe that by providing existing drill-and-practice software and microcomputers to lower-achieving students, such students can be helped to catch up to the others through a computer-based instructional intervention. These schools are trusting that the properties that advocates of computer-based drill claim for their method---increased student motivation, immediate feedback, and individualization of instruction---can be realized to the benefit of the participating students.

The other approach, which allocates microcomputers to the better-prepared students, assumes that the slower-learning students require more personal attention of professional teachers in order to master basic academic skills. By providing the faster-learning students with a challenge on which they can work independently for long periods of time, the teachers aim to prevent the classroom management problems that occur when a few students become bored with the slow pace of instruction.

Where Is the Microcomputer Having Its Biggest Impact?

A lot has been said about microcomputers affecting students, teachers, and the whole process of schooling, but there has been relatively little scientific investigation of their impact. This national survey can only provide limited indications of actual impact--to do better, we need well-designed studies using random assignment of students and teachers to different computer-based treatments, appropriate non-computer-based instructional methods delivering the same curriculum to control groups, and enough cases to allow for generalizing findings to a range of schools. However, this survey does allow us to learn how a representative sample of microcomputer-using teachers believe that having a microcomputer has affected their school. And we can investigate how these opinions about the computer's impact are related to the conditions under which the computer is used.

For the most part, microcomputer-using teachers in 1983 felt that the effects of microcomputers were more on the social organization of learning than on increased student achievement per se. Substantial numbers of microcomputer-using-teachers believe that micros have led to increased student enthusiasm for schooling; to students working more independently, without assistance from teachers; to students helping one another and answering each other's questions; and to students being assigned to do work more appropriate to their achievement level.

The microcomputer-using-teachers also believed that "above-average" students learned more than "average" or "below-average" students from having had a microcomputer in their school. For example, 24% of the teachers said that as a result of having a microcomputer there had been "much more academic learning by above-average students." Only 6% of the teachers said that the same was true for average students and 7%

said this was true for below-average students. (See Table 6.)

Table 6

Micro Impact as Viewed by the Computer-Using Teachers

"As a result of having a microcomputer, there has been MUCH MORE...	Percent "Much More"
General enthusaism for school by students using computers..	30%
Academic learning by "above-average" students........	24%
Students working independently, without being directly supervised....................................	18%
Students helping other students with their questions.	15%
Students doing work more appropriate to their own ability level..	12%
Academic learning by "below-average" students........	7%
Academic learning by "average" students..............	6%
Teacher rapport with students.........................	5%
Parent involvement in school activities..............	1%

Teachers in elementary schools and those in secondary schools came to similar conclusions about the relative value for high-, low-, and average-achieving students, even though microcomputers were being used in characteristically different ways in the two types of schools.

Acquiring and Using Microcomputers: Different Patterns, Different Results

Before 1982, the initial impetus for obtaining microcomputers most often came from a single teacher, in many cases a computer enthusiast of some expertise. In 1982 and 1983, though, administrators and groups of teachers more often took the responsibility to acquire and organize the use of microcomputers at their schools. The principal came to assume an increasingly large role in elementary schools, while in secondary schools, other school-based and district-based administrators accepted leadership roles. To cite just one statistic on these trends, in half of the schools that obtained a microcomputer before the 1981-82 school year, one particular teacher first brought up the idea of having a micro at the school. In the next two years, an individual teacher was the primary initiator in only about one-quarter of the schools obtaining their first micro during that time.

As schools began to acquire additional microcomputers beyond their first, groups of teachers often became involved. Parents also became influential in subsequent computer acquisitions, but this occurred primarily in elementary schools.

Schools differ in how well they are able to use their computers and which students have an opportunity to use them. And many of these differences correspond to particular patterns in how computers were first acquired and implemented. For example, in elementary schools whose first micro was acquired and implemented by a group of teachers, micros were in use for more hours of the week; there was greater computer use by below-average, average, and above-average students; they were used for a wider range of applications; and a higher proportion of the school's students used micros during the week.

Where a group of teachers led implementation activities, micros were typically in use for 19 hours each week; nearly twice the 10 hours per week that was typical in elementary schools in which a single teacher or the school principal took the major responsibility for organizing how the school's first micros would be used.

Perhaps the ideal pattern at the elementary school, though, is where both the principal and a group of teachers participated heavily in making computer-related decisions before and during the school's initial involvement with computers. In this situation, the survey respondents reported the most favorable results: more learning by all groups of students (above–average, average, and below–average), more mutual helping among students, and more enthusiasm by computer–using students.

In contrast, where a single teacher dominated acquisition and implementation in elementary schools, micros sat idle more often and, when used, they were used primarily to teach computer programming to the faster–learning students. At the secondary school level, it was also true that where an individual teacher dominated the organization of computer use, above–average students had disproportionate access.

At both elementary schools and secondary schools, but particularly in the higher grades, when administrators took a major role in deciding how microcomputers would actually be used, below–average students were much more likely to achieve parity of access to microcomputers in comparison with above–average students.

Whether equal allocation of computer time across various ability groups is the most beneficial allocation depends on whether computer–based learning activities are as helpful for the educational needs of below–average students as they are for above–average students. That is, an optimal allocation of resources would consider factors such as equity but also the effectiveness of providing instruction through the medium of the microcomputer as well. A survey such as this can raise these more fundamental questions, but can provide only limited evidence regarding their resolution.

The Location of Microcomputers in the School

Although most schools have fewer microcomputers than they have students in a single classroom, schools have made a variety of decisions about physically locating computers in their building.

Some schools have located their few microcomputers in one or more regular classrooms, to be used by individual teachers with their own class; others have placed microcomputers in common spaces like libraries, where teachers may send individuals or groups of students to use micros under the supervision of a school librarian. Other schools have established "computer laboratories," often containing only two or three computers, supervised when staff time can be allocated, by a computer specialist, most often drawn from the regular teaching faculty. Although most schools let their computers stay in place, some rotate them from room to room.

To study the impact of locational differences on patterns of use, a complex statistical technique called "multiple regression" was employed. This technique enabled us to statistically hold constant other factors that also are related to where schools put computers and to how they are subsequently used--for example, the number of students enrolled at the school, the number of micros at the school, the socio-economic status of the student body, and the presence of computer enthusiasts on the teaching staff. Although not as satisfactory a method for discovering causation as true experimental design, this technique is better than mere correlation, because alternative explanations for the observed patterns are ruled out by including them in the statistical model.

The analysis is summarized in Table 7. Each column of the table presents results for one way of thinking about "location." Each row indicates results for one of the "outcomes." Two entries are shown for each row-column intersection: the first is for elementary schools; the second, for secondary schools. A "+" indicates that there was substantially more of that outcome in those schools that located their micros in the way suggested by the column heading (e.g., in "classrooms only"); a "-" indicates substantially less of that outcome in comparison to other micro-using schools. A blank entry means that the difference was not statistically significant.

Table 7

Impact of Micro Locations on Patterns of Use

(Summary of Regression Analyses)

Note: Each row-column combination has two entries. The format is...

ELEMENTARY ENTRY / SECONDARY ENTRY.

The entries are " + " and " - " and mean...

+ : Substantially More in These Schools Than in Other Schools
- : Substantially Less in These Schools Than in Other Schools

	Classrooms Only	Computer Lab	Library	Rotate Micros Between Rooms
Number of Regular Teacher Users.......	- / -	+ / +	/ +	/ +
Number of Hours Per Week of Student Use.	/ -	+ / +	/	/ +
Breadth of Use Across 13 Applications.....	- /	/ +	/ -	/
Percent of Students Who Use Micro.......	/	+ /	/ +	+ / +
Dominance of Computer Programming Uses over Drill-and-Practice..	- / -	+ / +	/ -	- /
Equity Between Above-Average and Below-Average Students' Use.......	/ +	- / -	+ /	+ /
Computer Time Per Student User........	- / -	/ +	/	- /
Academic Learning Attributed To Micro Presence...	/	/	- /	- /
Social and Organizational Outcomes Attributed to Microcomputer....	/	/	- /	- / -

Computers in Classrooms. The first column of Table 7 suggests that restriction of microcomputers to classroom settings may have the following consequences: fewer teachers using computers in their teaching and a narrower range of uses being made of the computers in elementary schools. In elementary school classroom settings, microcomputers were used more for drill-and-practice than for programming instruction (in secondary schools, programming use was less dominant). Finally, classroom locations led to more equity in use between below-average and above-average students in secondary schools, but also the computers were used less overall--the machines were on less and there was less computer time for each of the students who did use a computer.

Computers in Labs. The second column of Table 7 suggests that putting some or all computers into a computer lab may have these consequences: regular use of the computer by a larger number of teachers; a broader range of uses being made of secondary school computers; student use of the micros for more hours of the week; a higher proportion of elementary school students using the computers at all; in secondary schools, longer turns at the computer by those who do use the computers, particularly for programming assignments; more intensive use of secondary school computers for programming activities; and more programming use than drill-and-practice use in elementary schools. In addition, elementary schools with computer laboratories reported much greater student enthusiasm for school, after controlling for the background variables. At the same time, labs may lead to a greater dominance of computer use by "above-average" students in both elementary and secondary schools.

Computers in Libraries. Placing microcomputers in the school library also has consequences for its use, as the summary data in the third column of Table 7 show. In particular, computers in secondary school libraries encourage computer use by more teachers, even more so than do computer labs. Also, at that level, having computers in the library means that more students will use them than when they are located elsewhere. However, student use is more restricted: there are fewer different uses made of micros in secondary schools where they are in the school library; and there is less intensive programming instruction, resulting in more equivalence between programming use and drill-and-practice use. Overall, in secondary schools with micros in the library, the machines are in use somewhat less of the time than schools with computer labs, but more than schools that keep their micros only in classrooms.

Elementary schools with a computer in the school library had more balance in use of the equipment between above-average and below-average students (other factors controlled); but teachers in such schools reported less positive learning outcomes and less positive social outcomes. "Enthusiasm" was particularly low among elementary schools with computers in their library.

Rotating Computers. The consequences of rotating microcomputers from room to room in elementary schools appear to be much the same as those of locating micros in the school library---more equity of use between above-average and below-average students, and poor reported outcomes for student learning and social aspects of computer use. (These analyses also control for the particular locations of the microcomputers, in order to see the effect of rotation *per se*.) Rotating microcomputers also results in access by a higher proportion of the school's students, but, elementary schools that rotate micros provide less computer time for each student user. There is also a tilt towards using microcomputers for drill-and-practice rather than programming instruction in the elementary schools that rotate equipment.

Locating Computers---in Summary. These analyses suggest that where schools locate microcomputers has an impact on how they are used. Keeping microcomputers solely in classrooms has largely negative consequences, although equity of use is improved for secondary schools. Putting computers into a laboratory situation, in contrast, has generally positive consequences, except for equity. Neither pattern, though, classrooms or laboratories, is related to respondent judgment regarding the academic or social and organizational consequences of having computers in schools.

Locating computers in libraries has a mixed impact. It may improve equity in elementary schools and increase use by teachers and students in secondary schools, but neither learning nor social organizational outcomes seem to be improved. Rotating microcomputers from room to room is generally positive for secondary schools and improves equity and access at elementary schools. However, computer-using students apparently get an insufficient amount of computer time to accomplish much learning.

It should be emphasized that these results are generalizations of trends observed in schools under many different particular circumstances. There were many schools whose portraits are not predicted by these statistical generalizations. But in thinking about possible consequences of locating computers in particular ways, the results may be helpful guideposts.

Arrangements in the Classroom: How Students Are Grouped for Computer Use

If a classroom contained enough microcomputers for all students to work with a computer at the same time, the distinction between classroom and laboratory use would largely disappear. However, at the time of the survey, almost all (about 6/7) of the elementary school teachers and nearly half of the secondary school teachers who had microcomputers in their classrooms had only one or two of them. Less than 20% of the secondary school teachers with micros in their classrooms had as many as eight microcomputers for classroom use.

Even with eight computers in the classroom, students may spend as much as three-quarters of their time in other activities while their classmates take their turn at the computer. Often, in order to more quickly cycle through all the students in the class, teachers will assign two or more students to a computer at the same time. However, most packaged computer programs available for schools assume that the computer is interacting with only a single student at a time.

Despite frequent pairings and larger groupings, there is still much waiting time, and teachers must find ways to occupy the students not using the classroom's computers. Options include "whole-class" instruction (everyone except the computer-using students having a single focus of attention), individual seatwork, or cooperative work in small groups.

To use computers effectively in traditional classroom instructional settings, teachers must organize classrooms with simultaneous multiple centers of attention. They must engage students who are waiting for their turn at the computer in profitable, not merely time-consuming, activities.

In our 1983 study, we found that teachers at elementary and secondary levels assigned students to computer work in similar ways. At both levels, about one-third of the time that students spent at the computer involved private study—-they worked alone and interacted minimally with other students. In another third of the time pairs of students worked together at each computer. The remaining time was spent in one of two ways: students worked individually, but received a lot of help from other students (about 20% of the total time); and students worked in groups of more than two at each computer.

Combining these categories in different ways, students spent slightly more than half of their computer time (54%) working individually rather than in pairs or in groups; but most of the time that students worked at computers (67%) they were in a social situation anyway, either working in pairs or groups or getting frequent help while doing individual work.

Arrangements for student use of computers varied significantly among schools covering different grade levels and by subject taught. Computer-using teachers in middle- and junior-high schools and those in K-8 schools (who primarily used computers with grades 6 to 8) reported greater use of paired activity than independent individual activity; whereas teachers of both older and younger students reported the reverse. And in junior high programming classes, teachers expected students who were working by themselves to get help from other students much more than did teachers at either higher or lower grade levels.

Waiting Time. Teachers using computers in their classrooms must decide how to organize the time of students who are waiting for their turn at the computers or who are not expected to use them. They can provide direct instruction in a lecture or discussion format; they can break students into work groups for cooperative activity; they can have students work individually at their seats until it is their turn; or they can have students watch the others who are working at the computer keyboards.

The most common way that this time is spent is doing individual seatwork. More than 40% of all student "waiting time" is spent that way, and about 40% of teachers report that "all" or "most" of this time is spent in seatwork activities.

Whole-class lecture or discussion is avoided when in-class computers are in use. Overall, direct instruction is provided during only 15% of the time that computers are in use in classrooms, and about half of the teachers say they never use whole-class activity while the computers are in use. Unfortunately, we have no data on how teachers allocate student activity in the absence of computers, so we cannot say how the presence of computers alters instructional patterns--whether, for example, it produces more seatwork and less direct instruction. It is plausible, though, that such a change in teaching style might result, considering the difficulties of periodically rotating students to computer activity while simultaneously maintaining a central focus of attention for the rest of the class.

In the 1983 survey, there was not enough information to learn how different classroom social arrangments for using computers affected what students learned--or even what teachers perceived that students learned. Only one respondent was contacted per school, and the data collected was a mixture of information about that teacher's own classroom teaching and what was occuring generally with computers in the school.

However, our sample does contain 120 secondary schools where the conditions were appropriate for analysis: the teacher-respondent was among only one or two regular instructional users of the school's equipment, the equipment was located in classrooms only--not laboratory situations; and the primary instructional use of computers was fairly similar--teaching computer programming and computer literacy.

In teaching programming to secondary school students, student enthusiasm was reported by these teachers to have improved most where students worked at the computer individually and without disturbance. Enthusiasm seems to have been least improved for these programming students where students worked in pairs. Also, secondary school programming instructors whose students worked individually reported more perceived learning--whether by above-average, average, or below-average students--when students worked at their programming tasks individually rather than in pairs or groups. These results held up even after controlling for the number of computers available to these students and for the overall extent that the teacher reported using computers.

This is not to say that computers are always best used by students working individually. Although the number of elementary schools that could be analyzed was quite small, the data seemed to indicate that, at this level, teachers perceived enthusiasm to be superior when students worked at computers cooperatively rather than individually, and learning was greatest for drill-and-practice activity when this was done in pairs or groups.

Some Interpretative Remarks

Few educational innovations have grown to command such large budgetary expenditures in such a short span of time as have microcomputers during the last few years. The effort going into obtaining computers, training teachers to use them, and providing students with access to them is remarkable. It is especially remarkable considering that an intellectual and empirical consensus for how computers are best used in formal group-instructional settings has not yet emerged. In comparison with school expenditures on computers and computer-related materials, scholars and researchers are putting comparatively few resources into addressing critical questions whose answers, ideally, should precede, not follow, the actions of practitioners--questions such as the following:

* What is the appropriate place of "computers" as an object of instruction in today's curriculum? Schools already have instructional goals that are often achieved with only limited success; e.g., mathematical concepts and applications, writing skills, scientific literacy, or, for many students, even basic math and verbal skills. Are "Computers" equally important? Does their inclusion draw effort away from more important curricular goals?

* Can the intellectual accomplishments of adolescent students in English, social studies, science, and other subjects be substantially improved by their use of computer-based tools? What prior learning and what classroom conditions are necessary for students to easily learn to use word processors, computer-based laboratory instruments, information storage and retrieval programs, and model-testing and forecasting programs? And, if these skills are in fact accomplished, what new levels of understanding and academic performance do such skills bring to adolescents?

* For which types of students and for what portion of the traditional curriculum are computers a cost-effective way of improving student skills and competencies? With the best available (or even the "best possible") educational computer programs, are there some students (e.g., slow learners or "gifted-and-talented") for whom some skills or competencies (e.g., decoding skills, scientific principles, or basic concepts of arithmetic) are learned better and faster through using computers instead of by alternative media or methods?

* How can computers be efficiently used in school settings, where teachers are responsible for supervising the activities of 25 or more students, but where computer screens and keyboards are typically used by individuals or pairs of students? Even if theoretically better for the instruction of individual students, how can schools of several hundred students use fewer than 15 computers--and how can individual students get enough computer time to be measurably beneficial?

In 1983, schools were confronting these issues as a result of having invested in a little of the new microcomputer technology. Their motives were admirable, but the problems of implementation were manifold.

They were attempting to use a very few computers in the context of parental demands for computer access for hundreds of students. Few recognized ahead of time the difficulties that such a few computers meant for instructional management in a classroom setting. Most acquired and tried to use computer hardware before spending resources either on teacher training or on curriculum development and integration. And many ignored other preconditions for effective computer use--for example, by having students use computer word-processors for writing without teaching them how to use a typewriter keyboard.

The problems created were not necessarily the fault of the schools. The social climate demanding universal ("equitable") access had made it difficult, if not impossible, to make rational judgments and comprehensive plans. In many cases, schools were only reluctantly drawn in to participation in computer-based learning, and they did what they could to fit computers into their traditional teaching practices.

As we have shown, given the circumstances in which schools obtained their first computers, the equipment came to be used primarily by the more independently-working "above-average" students, primarily at the higher grade levels, and it was with these students that computers had their greatest impact. Clearly, the major instructional outcome of microcomputers by 1983 was to increase the number of high school students who had some skill in computer programming and an understanding of computer concepts.

Such a consequence is not trivial--certainly not for the students involved. However, it will be necessary for schools to show further accomplishments with computers if they are to continue to draw support for further investment in expensive learning technology. (The "catch-22" in this, though, is that without enough computers to structurally integrate them into classroom teaching patterns, it will be difficult for schools to show substantial learning outcomes.)

To show results, schools will need more than simply more computers. They will need instructional programs (curricula, methods of instruction, systematic sequences of activities) that involve computers, but which are built around instructional goals, and defensible methods, not around computer programs. And these programs must be tested and refined until they prove successful--or abandoned for failing to make a substantial difference in student achievement, broadly defined.

The primary attitude of schools towards computers should be an attitude of open experimentation. Their immediate goal should be to learn as much as possible about the relative instructional consequences of using computers in different ways, for different students, and different subjects.

There are a number of approaches schools could take to learn these things, but one approach that I believe is very important for schools to consider is to become a partner in systematic collaborative research with researchers and with other schools.

Physicians treat people using their clinical expertise, but also by using the knowledge of the effects of drugs and medicines that has been established through painstaking, disciplined medical research. This research, usually undertaken by pharmaceutical or medical researchers, is often accomplished with the collaboration of practicing physicians themselves. The research takes a number of forms, but often it follows an experimental design where treatment is provided to certain individuals picked at random from a pool of eligible patients.

In the same way, schools, working with researchers, are in a position to participate in evaluating the impact of using computer programs in specific ways to provide instruction to specific types of students.

One aspect of such collaborative research involves a commitment from a school to focus on a single use of computers for a limited group of the school's students. An example of such a research project would be providing typing and word-processing instruction for students in the 9th grade who are at or below grade level on writing skills. Another example would be using alternative computer tutorials with different students to teach comprehension of fractional arithmetic.

Ironically, although the current "experimental" stage of using computers calls for much variety in how computers are used, it is important for each particular school to limit the ways that it uses computers. Because schools are often pressured to provide computer access to as many students as possible, too often a school's limited computer resources are spent in providing brief exposure to large portions of the student body. Often different departments or teachers split the school's available computers, preventing each from having enough machines to be used effectively with a single classroom of students.

The idea that computers might have a substantial impact on learning and instructional effectiveness only becomes plausible when computer resources can be aggregated so as to fit the organizational requirements of instruction in schools. Only under such arrangements can normal classroom instructional processes and activities be carried out and can students involved in a computer-based activity have a substantial enough experience with computers for a significant impact to be made.

A second aspect of this collaborative project model involves providing comparable instruction to comparable students using methods that do not involve computers. In the "typing and word processing" example above this would mean comparing the writing accomplishments of students using computers with similar students doing writing assignments in more traditional ways.

A third aspect of the collaborative project involves the school's willingness to use random assignment and other elements of experimental design in their research project. These principles are necessary in systematic research in order to prevent conclusions from being reached that are only spuriously related to the treatment itself.

For example, if we merely compare intact classes using different methods, differences in instructor or student abilities may be responsible for observed differences in achievement. It would be best to have the same teachers teach using both the computer-based and the non-computer methods that are being compared. Similarly, it would be best to randomly assign students to classes rather than employing intact classes which are likely to differ in systematic ways that might interfere with a fair comparison of the different instructional methods.

Finally, a collaborative research project would involve several schools undertaking the same contrasts in instructional methods, using the same software, with similar groups of students. Because in many respects the "unit of analysis" is the classroom, not the individual student, one would need many classes to participate--more than any one school could contribute.

Such a project would require the schools and the coordinating researcher to jointly decide upon an instructional goal or set of goals, a target student population, a method of providing a computer-based instructional program, an alternative instructional program aimed at the same goals (perhaps a pre-existing teaching plan), and measures of learning and achievement.

It is certainly more difficult to abide by these restrictions than to simply put the computers out there and informally observe what appears to happen. However, just as medical practice would be little improved if each generation of doctors used only informal observation and personal experience to prescribe treatment, so in education do we need to move from solely exploring the uses of computers to carefully designing programs that seem likely to have a big impact on students. These programs must be implemented responsibly and we must take the risk of objectively measuring the consequences of putting our designs into place. Finally, after using the apparently more successful programs with different student populations, we will learn the range of circumstances and conditions required for successful implementation of each program.

Along with the glamour and excitement surrounding the use of computers, we need to have some friendly, but rational skepticism, as well as a commitment to study and improve the impact of computers on students' development. We should be appreciative of the many efforts now being made to integrate computer programs with traditional teaching objectives and to create new and interesting computer-based activities for classroom settings. But we also need to carefully measure the actual consequences for student learning of these development efforts.

Today's microcomputers are actually quite limited precursors of other electronic tools that could be developed in the near future to help teachers accomplish their instructional tasks.

However, whether society continues to support investments in technology by schools will partly be determined by how well schools use the few "first-generation" microcomputers that they have been given so far. This is a tremendous challenge and responsibility for all of us.

For that reason alone, it is no longer adequate for schools to be merely "mucking about" with computers. It is time for each school to select one or two instructional problems for which computers seem to be a particularly appropriate tool, to carefully plan an implementation that seems likely to work, and to responsibly evaluate what was accomplished, so that the program can be extended, modified, or jettisoned depending on what is learned from its use.

To do this will require leadership, commitment, and time from administrators, teachers, computer software developers, and educational researchers. However, with an organized and sustained strategy for using computers to improve the effectiveness of school instruction, we might accomplish what has eluded education throughout recent decades—clear and obvious improvements in student accomplishment and in how much learning occurs during a day in school. Nothing would help the institution or its practitioners more.