

**Findings from the Teaching, Learning, and Computing Survey:
Is Larry Cuban Right?**

Henry Jay Becker

University of California, Irvine

hjbecker@uci.edu

July, 2000

Revision of a paper written for the January, 2000 School Technology Leadership Conference of the Council of Chief State School Officers, Washington, D.C.

For about 15 years, Larry Cuban has argued that computers, as a medium of instruction and as a tool for student learning, are largely incompatible with the requirements of teaching. Cuban points out that teachers have so many students to teach (or, in the elementary grades, so many different subjects to cover) that, along with the increasing accountability demanded of them, it is simply too hard for most teachers to incorporate student computer use as a regular part of their instructional practice. Moreover, computers are hard to master, hard to use, and often break down; therefore, investing effort into having students use them frequently is hardly worthwhile, and we should not expect many teachers to make this effort. Finally, all too often, district or school administrators have placed computers in teachers' rooms with the expectation that computers will become part of the teacher's instructional repertoire, even though the teachers did not ask for them and did not have specific plans for using them (Cuban, 1986; Cuban, 2000).

Yet, although Cuban's argument may have applied in the mid-1980's, is it correct today? The capabilities and functionality of what we call personal computers have changed by orders of magnitude since Cuban first wrote about desktop microcomputer technology. What passed for classroom computers fifteen years ago seem like primitive toys today. Because the early "8-bit" computers that dominated schools' installed base in 1985 stored, processed, and displayed information at a tiny fraction of the capacity and speed of today's computers, they required much more patience and personal interest in the technology itself than current technology demands. For example, in the mid-1980's, a serious computer-using teacher would have had to keep track of programs and student files on dozens of different floppy disks, but today the widespread use of hard disks and local area networks has eliminated much of that shuffle of materials. Software applications that in earlier years were frustratingly slow or markedly limited in their functionality have matured a great deal, providing much more in the way of on-line user help, even as they have come to provide more functionality. Moreover, the instructional possibilities that computers provided to teachers were much narrower then than now. New applications have evolved that hardly existed ten or fifteen years ago—electronic mail, the World Wide Web, software for presenting digital slide shows, student-created multimedia authoring environments, and digital video-editing, just to name some. Today, advocates for teachers using computers regard these new applications, embedded in current computer and communications technology infrastructures, as learning resources of a totally different sort from what pioneering teachers bravely attempted to use a decade and a half ago.

So, have computers become more compatible with the conditions of teaching? Have their richer capabilities made them more relevant to teaching objectives? Do they now constitute resources with potential for significantly changing and improving the nature of school learning? Have teachers themselves become more skilled and knowledgeable about using computer software and hardware with their students? Or is Cuban right even today: Are computers really a mismatch with the requirements and conditions of teaching?

The Teaching, Learning, and Computing Survey

Data from the 1998 national survey of teachers, Teaching, Learning, and Computing (TLC), suggests that Cuban's argument that teachers' "intractable workplace conditions" do still limit widespread classroom use of computers. However, under the right conditions—where teachers are personally comfortable and at least moderately skilled in using computers themselves, where the school's daily class schedule permits allocating time for students to use computers as part of class assignments, where enough equipment is available and convenient to permit computer activities to flow seamlessly alongside other learning tasks, and where teachers' personal philosophies support a student-centered, constructivist pedagogy that incorporates collaborative projects defined partly by student interest—computers are clearly becoming a valuable and well-functioning instructional tool.

In the TLC survey, more than 4,000 teachers in over 1,100 schools across the U.S. described their educational philosophies and characteristic teaching practices, their uses of computers in teaching, and various aspects of their school's environment. The survey included a nationally representative sample of 2,251 4th through 12th grade teachers as well as more than 1,800 other teachers from two targeted samples of schools—schools with the greatest presence of computer technology and schools that participate in one of more than 50 identified national or regional educational reform programs. Roughly 75% of the schools sampled for the study participated and nearly 70% of the teachers sampled within those schools completed 20-page survey questionnaires.¹

In this paper, I discuss some of the findings of this survey as they relate to the questions raised by Cuban's critique: Are teachers using computers with their students? Which teachers are doing so? What are their teaching objectives for students' computer use? How are those objectives met by using computers? Do certain approaches to using computers have an impact on students and on their teaching in general? What types of teachers are making these changes, and what conditions permit this to happen?

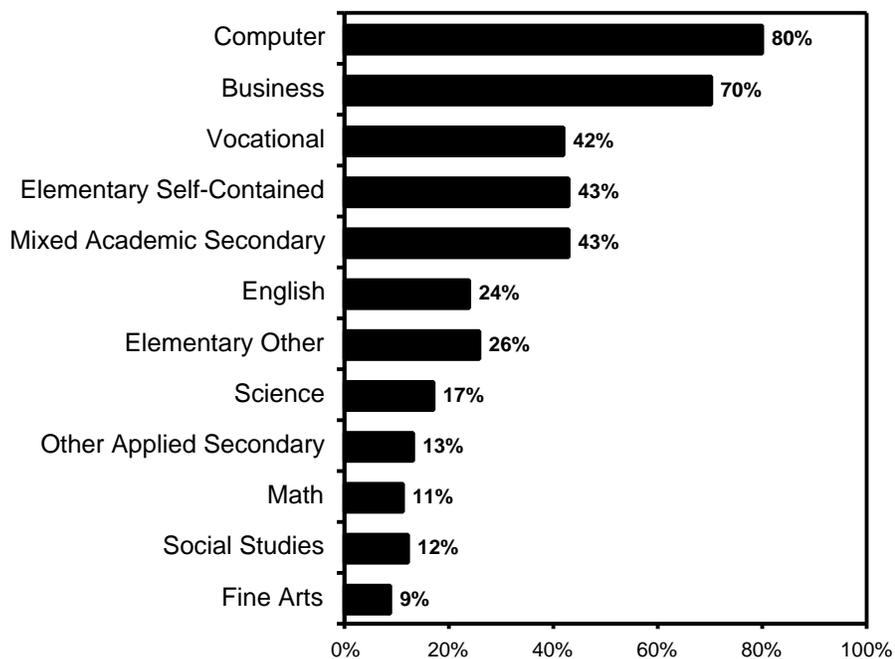
The Most Common Frequent Uses of Computers Are in Computer Classes and Business Classes

Although computers in schools by now number over 10 million, frequent student experiences with school computers occur primarily in four contexts--separate courses in computer education, pre-occupational preparation in business and vocational education, various exploratory uses in elementary school classes, and the use of word processing software for students to present work to their teachers. The one area where one might imagine learning to be most impacted by technology—students acquiring information, analyzing ideas, and demonstrating and communicating content understanding in secondary school science, social studies, mathematics, and other academic work—involves computers significantly in only a small minority of secondary school academic classes.

Figure 1 shows the proportion of teachers, by subject, who reported that a typical student in one of their classes used computers on more than 20 occasions during class over roughly a 30-week

period. Apart from computer education teachers, a majority of only one other group—business education teachers—reported computer use occurred that frequently in their classes. About two-fifths of vocational education teachers and elementary teachers of self-contained classes also reported frequent (i.e., roughly weekly) use. Among secondary academic subject teachers, the highest rate of frequent use was reported by English teachers (24%). Only one out of six science teachers, one out of eight social studies teachers, and one out of nine math teachers said students used computers that often during their class. Given the distribution of course-taking patterns in high school, it turns out that a majority of students' intensive computer experiences occur outside of academic work, as part of computer education or occupational preparation.

Figure 1
Frequent Student Use of Computers by Subject (i.e., Typical Student Used Computers in Class More Than 20 Times Over Most of School Year)



Sample: Probability sample; questionnaire versions 1 and 2.

Why is this the case? From the survey's findings, there appear to be at least five elements to an explanation.

One problem is scheduling. Most secondary students have a continuous block of less than one hour's duration to do work in any one class. That time limit constrains the variety of learning modalities their teachers can orchestrate. As a result, fewer teachers plan computer activities on a regular basis. In the TLC survey, secondary academic teachers who work in schools with schedules involving longer blocks of time (e.g., 90-120 minute classes) were somewhat more likely to report frequent (i.e., roughly weekly) student use during class (19% vs. 15%), even though they met those classes on perhaps half the number of days as teachers who taught in traditional 50-minute periods.

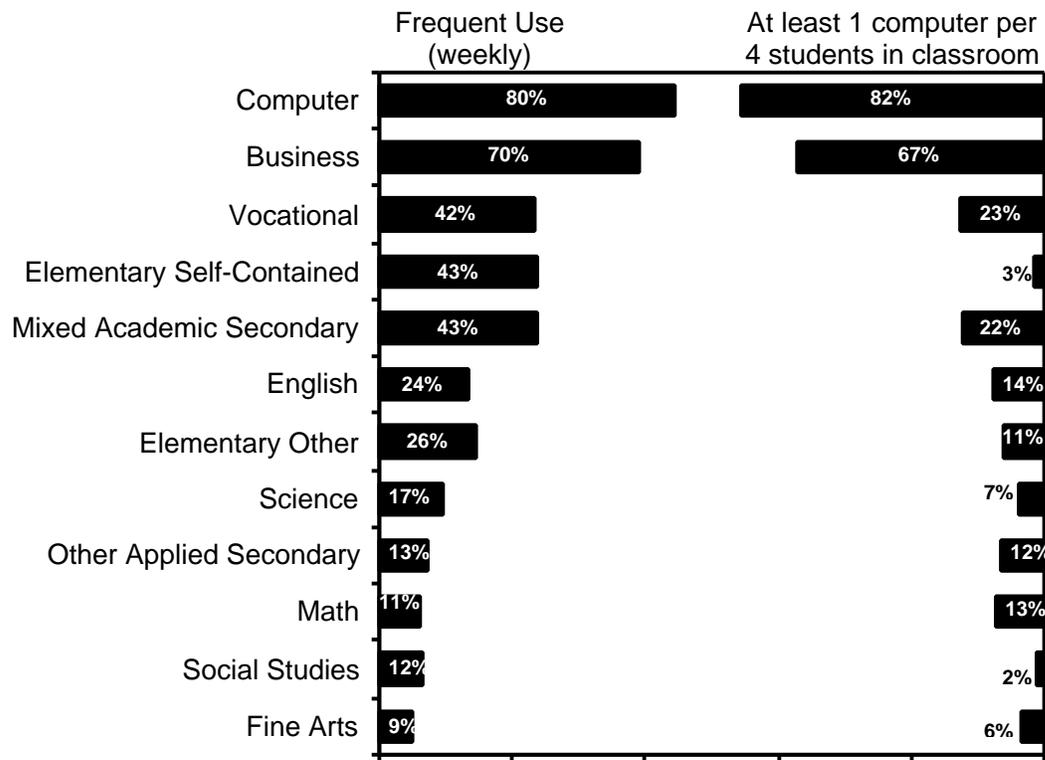
A second issue is the pressure of curriculum coverage. Teachers of academic subjects are strong believers in transmitting a large amount of information or skills during the course of a year. Our data show that secondary mathematics and social studies teachers and high school science teachers believe more strongly than other teachers of the importance of broad content coverage of their curriculum. In addition, many teachers feel pressured by administrator expectations for content coverage, particularly content to be covered on high-stakes tests. Those pressures are strongest among elementary teachers, math teachers, middle school social studies teachers, and high school English teachers. Computer use is often seen as inhibiting the coverage of topics. In fact, the relatively few academic teachers whose pedagogy involves "a small number [of topics] covered in great depth" (only one out of every thirteen academic secondary teachers in the study) are twice as likely as those who report covering a large number of topics to assign computer activities to their students on a frequent basis (29% vs. 14%).

A third issue has to do with convenient access to computers. This factor is so important, it deserves special consideration.

Classroom Access to Clusters of Computers: More Frequent Use Than Labs Produce

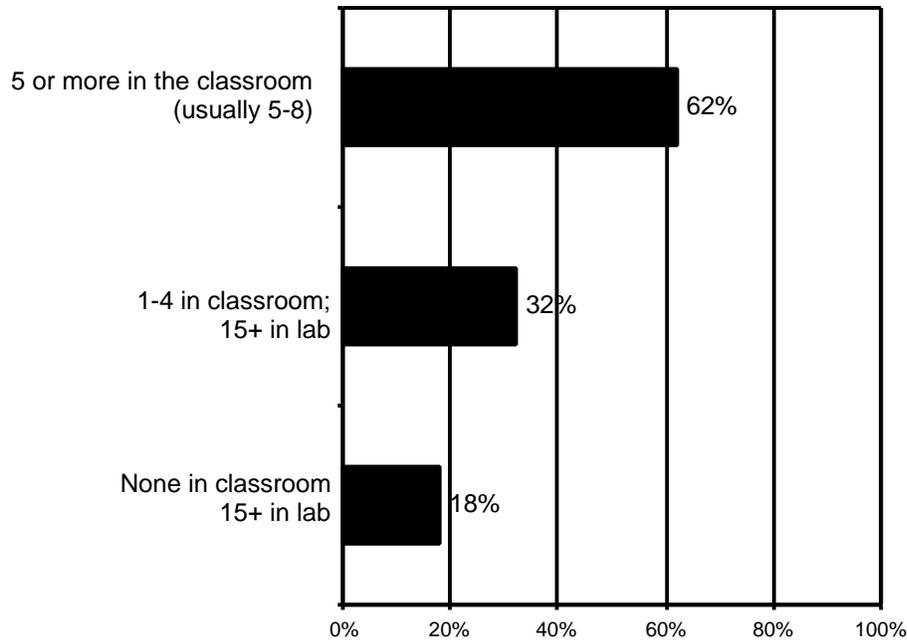
Across the various subjects taught in school, there is a strong relationship between how frequently students use computers during class time and whether their classroom has a substantial number of computers present. Those school subjects where teachers are more likely to have a 1:4 ratio of computers to students (that is, one computer for every four students) are the same subjects where frequent use of computers is more likely. Figure 2 shows this quite clearly: the subjects where frequent student use is common are the subjects where clusters of classroom computers are equally common. The only real discrepancy in the pattern is that elementary teachers of self-contained classes have students use computers more frequently than one would predict solely based on how many computers they have in their classroom. The obvious explanation is that elementary teachers have their students for most of a school day rather than 50 minutes at a time. Thus, they have a greater opportunity to provide frequent computer experiences for each student. However, at the secondary level, where 50-minute instructional periods are the norm, the pattern is very strong: in math, social studies, and foreign languages, the subjects where students use computers the least often, very few teachers have more than one or two computers in their classroom.

Figure 2
Frequent Use and Classroom Access by Subject



Sample: For statistics on computer to student ratios of 1:4, all teachers in probability sample. For statistics on frequent use of computers, probability sample; questionnaire versions 1 and 2.

Of course, most teachers have the option of using computers in shared spaces such as computer labs or media centers, where large numbers of computers may be present. (The typical computer lab has 21 computers.) However, despite such settings having so many more computers than in most classrooms (the typical number of computers in classrooms that have any at all is still only 2), teachers with a reasonable number of computers available in their own class are much more likely to provide frequent opportunities for students to use computers than when they have to make use of a computer lab. Specifically, we found that secondary academic subject teachers who have 5 to 8 computers in their classroom are twice as likely to give students frequent computer experience during class than teachers of the same subjects whose classes use computers in a shared space with a minimum of 15 computers present. (See Figure 3.) This may seem counter-intuitive since being in a lab with three times as many computers as these classrooms have would seem to be preferable. However, the scheduling of whole classes of students to use computers, at wide intervals determined well in advance of need (i.e., weekly or every-other-week use scheduled weeks in advance) makes it almost impossible for computers to be integrated as research, analytic, and communicative tools in the context of the central academic work of an academic class.

Figure 3**Frequent Computer Use by Location and Number of Computers Available
(Selected Combinations), For Secondary Academic Teachers**

Sample: Probability and purposive samples; questionnaire versions 1 and 2; teachers who used computers with their selected class.

This analysis does not take into account the economies that centralized placement of computers involve. In other words, if a school's 12 science teachers, for example, each had five computers in their classrooms instead of together sharing 30 computers in a computer lab, this would require twice as many computers in total. Instead, what we are examining is the relative likelihood that students will receive a substantial computer experience during instructional time. If the 12 science teachers each taught five classes of students, the 60 classes would have at most only one opportunity to use computers in the lab every two weeks. On the other hand, if the computers were constantly present in every student's science classroom, one would expect them to have more opportunities to use computers for doing scientific work, particularly if their teachers' instructional practice enabled different students to be using different resources at the same time.² If centralized placement of computers does not result in students getting a substantial experience with using computers in doing academic work, the apparent economies of scale are not likely to be cost-effective in the end.

Teacher Expertise and Comfort in Using Computers Professionally

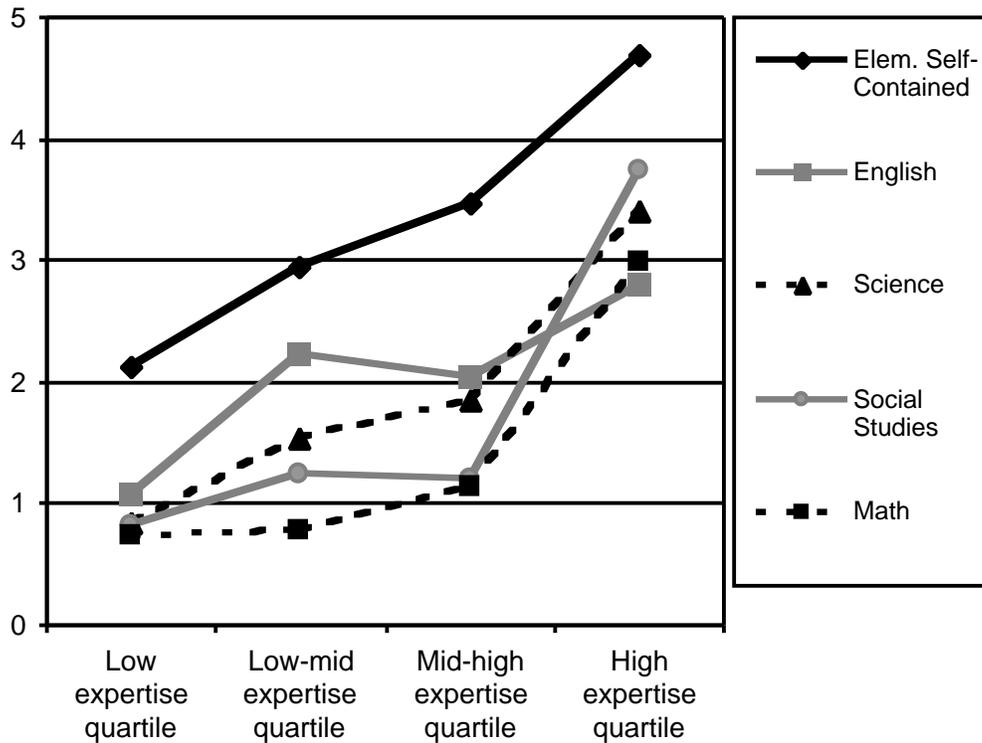
Besides inconvenient access to clusters of computers, besides problems of overly-scheduled secondary schools, and besides problems related to having a large amount of curriculum to “cover,” another element that prevents more teachers from using computers frequently with their students is their own limited skill and expertise in using computers themselves.

Many teachers have learned information technology skills and put them to use over the past five to ten years. A majority of the teachers in the nationally representative TLC sample said they know how to use a World Wide Web search engine, more than a third said they would be able to create a new database and establish fields and screen layouts, and one fourth said they could prepare a slide show using presentation software. Nearly one third report using either camcorders, digital cameras, or scanners at least occasionally, and many teachers³ have even posted ideas, lesson plans, or student work on the World Wide Web. On the other hand, the most widespread professional uses of software by teachers are fairly routine—preparing handouts, writing lesson plans, and recording and calculating grades. And though most teachers *do* report using the Web to get information to use in their lessons, most do so on a relatively infrequent basis. At least that was the case in 1998, when the survey was conducted.

But do the teachers who have those skills and who regularly use computers for their own purposes use computers more frequently with students or do so in a different way than less computer-knowledgeable teachers? Cuban (2000) claims that insufficient technical skills is not holding back teachers’ classroom use of computers. However, our data suggests that they very much are. Teachers who have a reasonable amount of technical skill and who use computers to address their own professional needs use computers in broader and more sophisticated ways with students than teachers who have limited technical skills and no personal investment in using computers themselves.⁴

To conduct this analysis, we divided teachers into equal-sized groups based on an index measuring the variety of their self-reported computer skills, the different ways they used computers professionally, and how extensive their experience was on different computer platforms. The teachers in the top 25% on that Computer Knowledge index, on average, had students use three times the number of types of software as did teachers in the bottom 25%. Figure 4 shows that the pattern is even stronger for teachers of individual secondary academic subjects. The biggest difference is between teachers in the upper 25% and the rest of the teachers; that is, the math, science, English, and social studies teachers who are most skilled and involved in using computers themselves account for most of the situations where students use a variety of software to do work for their academic classes.

Figure 4
Breadth of Software Use by Teacher Computer Expertise by Subject Taught



Sample: All teachers in probability sample.

There are several types of software which the more computer-knowledgeable teachers are more likely to have students use than are teachers with less computer knowledge: (1) presentation software such as Powerpoint, (2) World Wide Web browsers, (3) electronic mail, (4) spreadsheets and database software, and, (5) in English, social studies and elementary classes, multimedia authoring software. The one type of software that is clearly NOT used by students of these computer knowledgeable teachers more than by students of other teachers is skills-practice software, i.e., traditional computer-assisted-instruction. (The more knowledgeable teachers don't have students use skills practice software *less* than other teachers; they just use other types of software much more.) Table 1 shows, subject by subject, the correlation coefficients between the Computer Knowledge index and how extensively teachers in that subject use different types of software with their students.⁵

Table 1
Correlations Between Teacher Computer Knowledge - Professional Use and
Extent of Instructional Use of Different Types of Software, By Subject Taught

	English	Social Studies	Science	Math	Other Secondary	Elementary
Skill Games	0.14	-0.01	0.02	-0.08	-0.01	0.08
Simulation/Exploratory	0.09	0.28	0.23	0.14	0.19	0.21
CD-ROM Reference	0.16	0.23	0.21	0.23	0.10	0.21
Word Processing	0.24	0.29	0.21	0.32	0.22	0.29
Presentation Software	0.38	0.32	0.34	0.25	0.36	0.27
Graphics Oriented	0.28	0.11	0.05	0.24	0.25	0.23
Spreadsheet/Database	0.21	0.28	0.28	0.32	0.31	0.19
Multimedia Authoring	0.25	0.31	0.16	0.16	0.34	0.32
WWW Browser	0.30	0.45	0.15	0.36	0.27	0.31
E-Mail	0.25	0.31	0.27	0.20	0.21	0.24

Sample: All teachers in probability and purposive samples.
 Highlighted cells have correlations of .30 or above.

One might ask, however, why the differences in Figure 4 and Table 1 are not even greater than they are. Our evidence suggests that a powerful limitation on broadening teachers' use of computers with students derives from teachers' personal philosophical beliefs about the basic nature of student learning and what type of instruction is optimal given their own implicit theory of learning.

Teaching Philosophy and Objectives for Computer Use

Traditionally, teaching practice has been characterized by an emphasis on skill and knowledge transmission from teacher to students. This usually involves

1. the use of an externally prescribed curriculum of discrete skills and factual knowledge;
2. direct presentation and explanation to students of that procedural and factual knowledge;
3. frequent assignment of written exercises to students aimed at their remembering factual knowledge and accurately performing skills; and then
4. evaluation of students' mastery of skills and knowledge by giving them written tests that prompt students to recognize factual statements and to apply learned algorithms and other skills to produce correct answers.

Transmission pedagogy derives from a conventional theory of learning in which understanding arises from carefully planned direct instruction on a narrowly defined skill or content topic and guided practice on questions related to that topic. Such a pedagogy is similar to conventional (i.e., culturally normative) beliefs about learning, and is therefore part of most teachers' own schooling experiences. Moreover, assessment of factual knowledge and specific skills can be accomplished with a fair degree of reliability and validity, both through teacher-constructed tests and in the kinds of large-scale external assessments teachers are increasingly judged on. Using such tests as measures of academic accomplishment, transmission pedagogy has been supported by a good deal of evidence from studies of reading, language, and arithmetic instruction, particularly in the elementary grades.

However, transmission pedagogy and the tests which certify its accomplishment, are primarily oriented towards only a narrow range of academic competencies, those emphasizing isolated mental processing on tasks with only a surface resemblance to deep understanding of a domain. Even the most recently constructed large-scale assessments of student achievement may have a built-in bias towards a transmission model of instruction and fail to capture a range of important competencies. Take, for example, the challenge of extracting from a large, messy collection of information and ideas a subset of evidence that is most relevant to constructing a good argument about a controversial issue; developing an argument that addresses the issue in consultation with other classmates, outside resources, and using analytic tools available; and then making the most cogent presentation possible to an audience that personally cares about this issue. Most “standards-based” assessments would not even attempt to judge students’ abilities to give such a “performance of understanding” (Perkins, 1998), in part because the “standardized” nature of such an assessment would not permit students to employ the particular analytic tools and information resources they were familiar with, such as computer software, to help them accomplish the task.

At any event, our data suggests that academic subject-matter teachers who use computers most productively in grades 4-12 are not very comfortable with a transmission-oriented pedagogy, even though that is the approach which may satisfy policy-makers and large portions of the public through realizing higher standardized test scores. These teachers, instead, implicitly if not explicitly, endorse an alternative philosophy of teaching, which might be explained as including two pedagogical emphases:

1. attending to the “meaningfulness” of instructional content for each student—for example, by developing examples connected to students’ own personal experience or by providing opportunities for students to present detailed explanations of their reasoning; and
2. developing students’ capacities to understand a subject deeply enough, and see the interrelationships of different ideas and issues, so they are able to know how and when to apply their knowledge to particular contexts and communicate their understandings to others.

Both of those emphases require substantial amounts of time and teaching expertise to accomplish, and both usually conflict with the objective of covering large amounts of curriculum. These emphases are associated with the theory of learning called “constructivism.” Constructivist theory claims that understanding comes from a person’s taking the effort to integrate newly communicated claims and ideas with his own prior beliefs and understandings. In that view, understanding cannot be transmitted, nor does skills-practice result in understanding which can be automatically applied as needed. Instead, good teaching involves creating environments in which students take mindful effort towards developing their understanding, and have opportunities to learn how to apply their knowledge and when to do so. Instruction is particularly valued that gets students to articulate their understandings and defend them against contrary points of view. Many ways of using computers lend themselves to instruction based on a constructivist model of learning—for example, presentations to a critical audience, integrating different perspectives in a report or multimedia document, or examining contrary assumptions using a spreadsheet model.

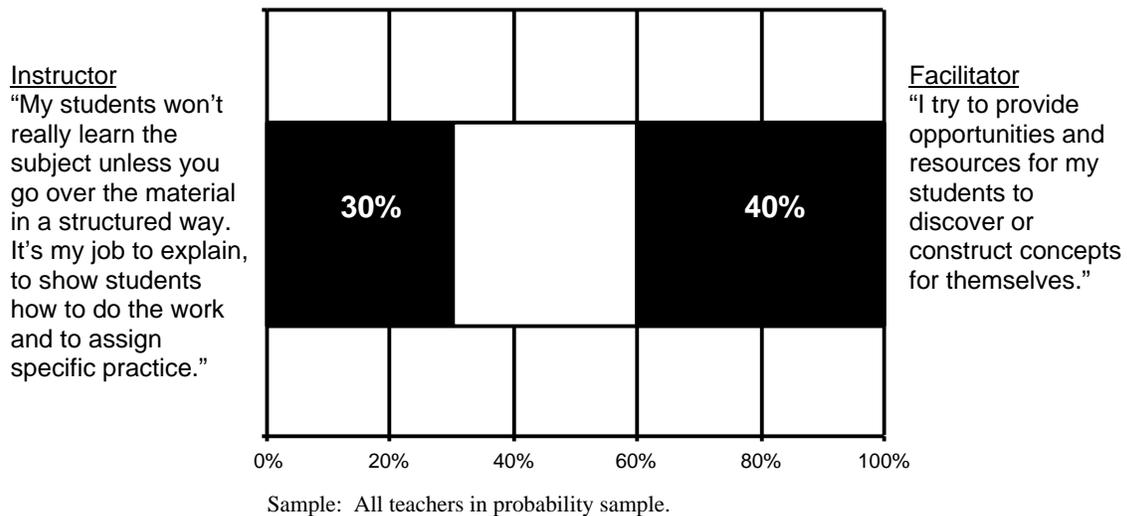
The way that a teacher uses computers gives an indication of her underlying pedagogical philosophy. Of course, any computer application *could* be used in a transmission-oriented pedagogy. That is, a teachers *could* focus students' use of multimedia, word processing, or spreadsheet software by teaching them a set of technical skills primarily so they can master the software itself. However, apart from school subjects where such skills are expected to be taught—computer education courses, or business education courses perhaps—teachers would generally not have students use complex software unless they found that it facilitated learning in the subject they teach. Thus, in academic subjects, we would predict that teachers who believe in a more traditional transmission-oriented approach will find most applications of computer technology incompatible with their instructional goals, and will therefore use a more limited range of computer applications.

To examine this argument empirically, the TLC survey asked teachers a relatively extensive set of questions designed to measure their philosophical preference between transmission-oriented teaching and constructivist-compatible teaching. We found clear relationships between teaching philosophy and (a) whether a teacher used computers with students; (b) the particular objectives for computer use the teacher had; and (c) the types of software used frequently with students. Moreover, constructivist-compatible teaching objectives for computer use (i.e., those most associated with constructivist teaching philosophies) were also found to be associated with a greater amount of school-related computer activity by students, before- or after-school or at home—that is, on the students' own time. Finally, teachers who used computers in a constructivist way reported making more general changes to their characteristic pedagogy than did teachers who used computers in a more limited way or not at all. The remaining set of figures and tables illustrate those findings.

Teachers' Philosophical Positions

Survey questions about teachers' philosophy were of several types. In one type, illustrated in Figure 5, teachers were given two alternative statements of teaching philosophy—for example, a statement that argued for structured presentation and explanation of information versus a statement that argued for the teacher being a provider of resources for students “to construct concepts for themselves.” In another set of questions, two teachers' contrasting practices of conducting recitations were described. One teacher asked a rapid series of direct questions, designed to keep students attentive and on-task. The other teacher encouraged questions from students, and used these as springboards for suggesting student-initiated research activities.

Figure 5
Teacher As Instructor or Facilitator



Overall, teachers’ responses reflected quite varying philosophies. For example, about 40% of teachers felt that the teacher acting as facilitator was preferable to giving structured explanations, while 30% felt the reverse was true and 30% gave the middle or ambivalent response. Slightly more teachers felt that rapid-fire direct-questioning teaching resulted in students gaining more knowledge than the opposite approach, but a majority of teachers felt that “skills” would be learned more in the class where teachers led students towards their own investigations into their own questions.⁶

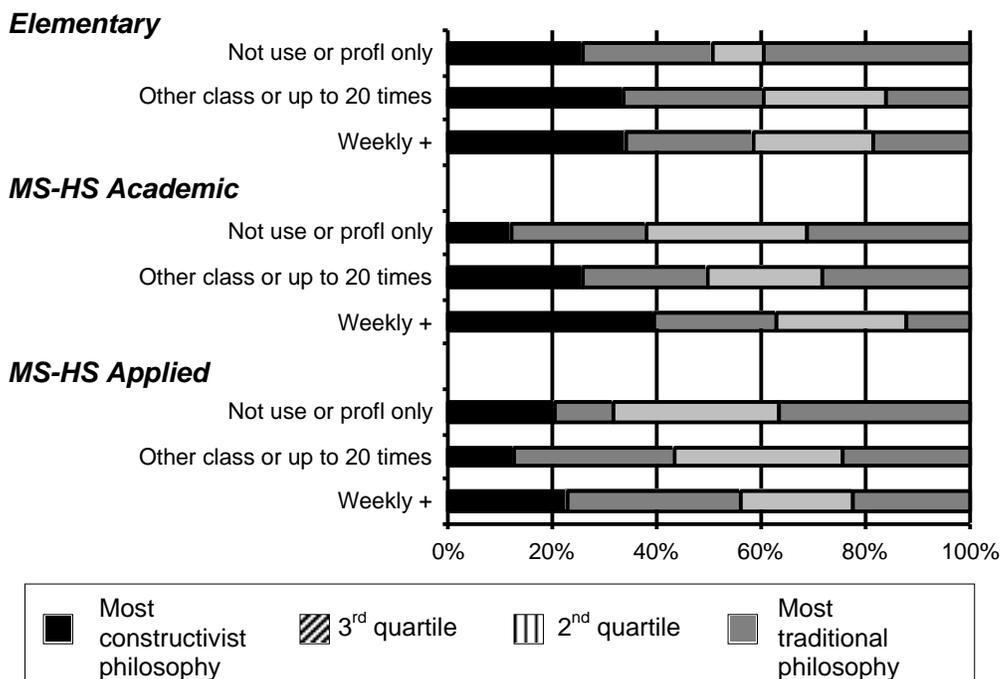
Other survey questions suggesting a transmission-oriented philosophy dealt with the value of a quiet classroom for learning, the importance of background knowledge and basic reading and math skills for “meaningful” subject-matter learning, having the teacher be the sole determinant of classroom activities, and building instruction around problems with clear, easily found, single correct answers. Questions (and responses) suggesting a constructivist philosophy argued for the value of “sense-making” over curriculum-coverage, the utility of organizing a class with multiple activities occurring simultaneously, the value of student interest and effort in academic work over the particular content covered in subject textbooks, and having students play a role in establishing criteria for evaluating student work.

To analyze these competing philosophical viewpoints about teaching, we again divided teachers into four equal-sized groups, from the quartile (25%) who most valued a transmission approach to the quartile who most valued a constructivist approach. Not surprisingly, elementary teachers turn out to be more constructivist than secondary teachers, with 32% of the elementary teachers in the “high constructivist” quartile compared to 21% of secondary (middle and high-school) teachers. (Middle school academic subject teachers are about half-way between the high school and elementary group.)

Computer-using teachers—that is, teachers who have their students do any computer work during class at all—are distinctly more constructivist than non-using teachers. Among

elementary teachers, relatively infrequent users are no less constructivist than teachers who have students use computers a lot. However, among secondary academic subject teachers, the teachers who assign computer work frequently are much more constructivist than those who make computers are less central part of their pedagogy. (See Figure 6, middle panel.)

Figure 6
Frequency of Computer Use by Teacher Philosophy
Among Elementary, Academic, and Applied Subjects

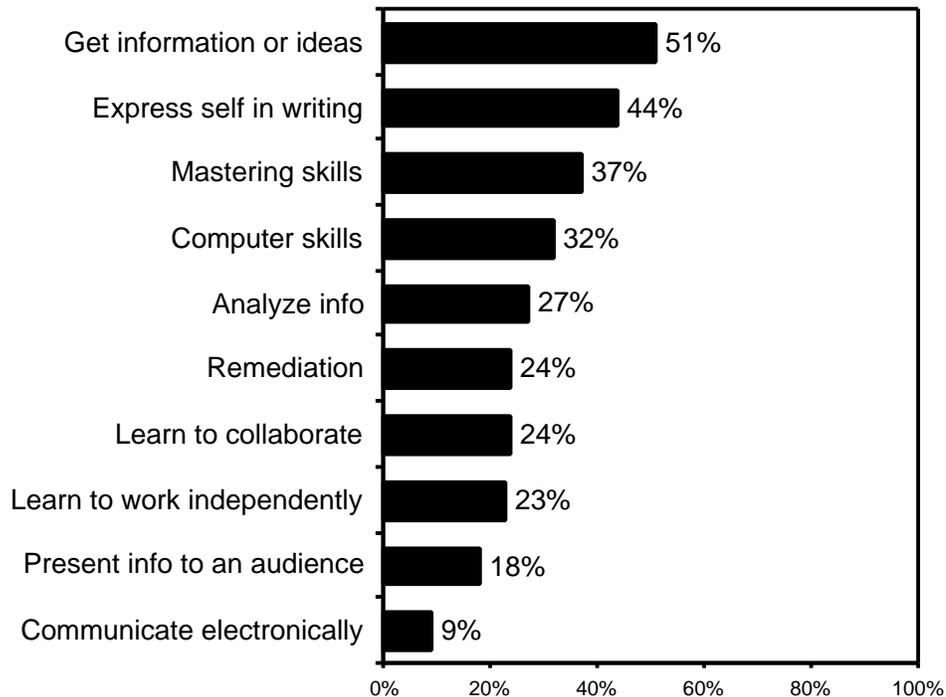


Sample: All teachers in probability sample.

Computer-Using Teachers’ Objectives for Student Computer Use

There is a strong relationship between teachers’ general philosophical viewpoint about what constitutes good teaching and the particular objectives they view as most central to their use of computers with students. The survey asked teachers to select three objectives from a list of ten that were their most important objectives for student computer use. The objectives most commonly supported by computer-using teachers were “getting information or ideas” and “expressing themselves in writing.” Mastering skills, both academic skills and computer skills, were less often cited, but “skills” as objectives were much more often cited than such objectives as “presenting information to an audience” or “communicating electronically with other people.” (See Figure 7.)

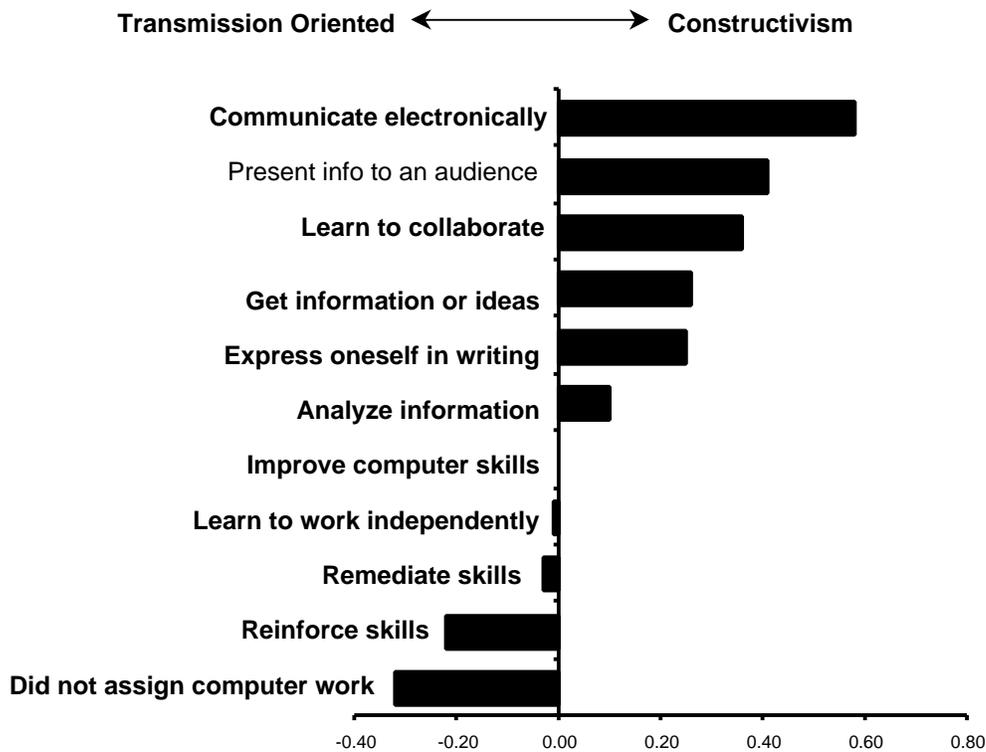
Figure 7
Teachers' Primary Objectives For Computer Use
 (% of Teachers That Report the Following Objectives As Among Their 3 Most Important)



Sample: Probability sample; teachers who used computers with their selected class.

The relationship between objectives and teaching philosophy is shown in Figure 8, where objectives for computer use are ordered according to how “constructivist” teachers were in terms of their survey answers to questions about teaching philosophy.⁷ Figure 8 shows that the relatively small minority of computer-using teachers who selected having students “communicate electronically with other people” (only 9% of all computer-using teachers) had, overall, the most constructivist philosophies. The next-most philosophically constructivist teachers were those who chose “presenting information to an audience” and “learning to work collaboratively” as their main objectives for student computer use. Teachers who selected “getting information or ideas” or “expressing themselves in writing” were also more constructivist than most teachers overall, but about average when just considering teachers who used computers with students.

Figure 8
Objectives For Computer Use Are Also Linked To Teaching Philosophy
(Transmission Oriented vs. Constructivism)



Sample: Probability sample; teachers who used computers with their selected class.

In contrast to those teachers, the 36% of computer-using teachers who selected skills reinforcement as one of their top three objectives (“mastering skills just taught”) reported much more transmission-oriented philosophies than teachers who chose other objectives. However, even the skills-reinforcement-valuing teachers were somewhat more constructivist (i.e., less transmission-oriented) than the teachers who didn’t have students use computers at all.

Types of Software Used by Teachers Who Assign Computer Work Frequently

The rapid progress of computer technology over the past decades has meant an increasing variety of software has become available for teachers to use with students. During the 1980’s, teachers could have students program in BASIC or LOGO, use drill-and-practice software, simple word processing programs, or some inventive problem-solving puzzles and simulations, but not much else. The range of possibilities has grown enormously since then. Our survey asked teachers to name the software that has been most valuable in their teaching—the best computer programs their students have used. Table 2 shows that general office tool software clearly dominates the list of the programs most commonly named as “most valuable.” *Clarisworks* was by far the software title most frequently named by teachers. Three of the five next-most commonly named were *Microsoft Works*, *Microsoft Word*, and *Microsoft Office*. (The other two were *Netscape*, reflecting the importance of Web activity; and *Hyperstudio*, the primarily Macintosh-based

multimedia student authoring environment named primarily by elementary teachers and middle school social studies teachers.) Some software titles focusing on specific curricular areas were frequently named as well, including *Geometer's Sketchpad* in mathematics, the inquiry-oriented conjecturing tool; *Autocad* in vocational education, which has dominated the growing field of computer-aided-design; *PhotoShop*, in fine arts classes; and *Accelerated Reader*, the computer-based test library used in off-line tradebook reading programs in elementary and middle-grades reading and language arts programs.

Table 2
Specific Software Reported As "Best" or "Most Valuable" For Students
by Computer-Assigning Teachers, by Subject & Level of Teacher

	Percent of All Computer-Assigning Teachers (naming at least one program as "best")*			
	20%+	15-19%	10-14%	5-9%
Elementary Self-contained	ClarisWorks		Hyperstudio	Accelerated Reader** , Encarta, Groliers, M. Word, Netscape, Oregon Trail , Writing-Pub. Center
Elementary Other	ClarisWorks	Accelerated Reader	Hyperstudio	Groliers, M. Works, Netscape, Writing-Pub. Center
English		ClarisWorks, M.Works	M. Word, Netscape	Accelerated Reader , Powerpoint
Science		ClarisWorks, Netscape		Hyperstudio , M.Office, M.Word, M.Works
Math	Geometer's Sketchpad	ClarisWorks		Excel, Math Blaster , M.Word, Netscape
Social Studies		ClarisWorks, Netscape	Hyperstudio	Encarta, Groliers, I.E., M.Word, M.Works, Powerpoint
Foreign Language	ClarisWorks, M.Word	M.Publisher	Netscape	M.Works, Powerpoint
Misc. Academic Secondary	ClarisWorks		Encarta, M.Word, Netscape	Groliers, M.Office
Computers		M.Office, Netscape	ClarisWorks, M.Word, M.Works, Word Perfect	Excel, Hyperstudio , Powerpoint
Business	M.Works, Word Perfect	M.Office	M.Word	ClarisWorks, Excel, Netscape
Vocational	AutoCAD	Netscape	ClarisWorks, Word Perfect	M.Office, M. Works
Fine Arts	ClarisWorks	PhotoShop	Netscape	Hyperstudio , M.Word, M.Works, PageMaker
Other Applied Secondary	ClarisWorks	M.Word, M.Works, Netscape, Powerpoint		Hyperstudio , M.Office, Word Perfect
Elementary	ClarisWorks		Hyperstudio	Accelerated Reader , M.Word, Netscape, Encarta, Groliers, M.Works, Oregon Trail
Middle School High School	ClarisWorks		Netscape Netscape, M.Works ClarisWorks, MWord	M. Works, M.Word, Hyperstudio M. Office, Powerpoint, Word Perfect
All comp.-assigning teachers		ClarisWorks	Netscape	M.Word, M.Works, Hyperstudio , M.Office

Probability and purposive samples; teachers who assigned computer work to selected class and who named at least one program. *One-half of teachers responded to a question about the "best computer programs students in this class have used." The other one-half responded to a question about their most valuable software in each of the past five years. Data from the two most recent years were taken from this latter group, and only if the software did not seem to be named primarily because of its value for the teacher's own professional use.

** Software in bold are applications other than office software, Internet access software, or CD-ROM encyclopedias. They are primarily subject-specific applications or authoring tools.

But overall, what is the balance of different types of software that teachers use on a frequent basis with students, and what teaching philosophies and instructional objectives do these types of software reflect?

Although many teachers have students use a variety of software at least occasionally, the only type of software which commands both broad use (across subjects) and frequent use (used by students for at least 10 lessons) is word processing. Frequent use of all other applications is limited to at most one or two specific subjects (usually computer education). Table 3 shows the percent of teachers, by subject, who reported having had students use each of ten types of software for at least 10 lessons during the school year. Highlighted in Table 3 are the types of software where at least one-fourth of all teachers of a given subject reported that level of frequent use. Word processing reaches the “frequent-use one-quarter penetration” criterion for elementary teachers and secondary English, computer education, and business teachers and nearly approaches that level for science and social studies teachers. Nearly half of all computer education and business teachers also report having students use spreadsheet and database software frequently.

Table 3
Percent of Teachers Reporting Frequent Student Use (Use In At Least 10 Lessons),
by Type of Software and Subject & Level Taught

	Word Proc.	CD-ROM	World Wide Web	Skill practice games	Simulations/ Exploratory Environments	Graphics	Spread-sheets/ Database	Presen-tation	Multi-media	E-mail
<i>Secondary</i>										
English	38	10	12	4	2	6	2	4	2	2
Science	24	15	22	3	5	6	8	5	2	4
Math	4	2	4	13	8	1	4	2	1	1
<i>Social</i>										
Studies	20	16	14	2	3	5	4	5	6	6
Computers	76	15	38	20	22	23	43	29	13	9
Business	78	3	14	16	19	20	47	22	2	5
Vocational	15	12	15	1	21	16	7	6	3	3
Fine Arts	10	4	7	0	1	15	0	1	2	1
<i>Elementary</i>										
All teachers	46	28	12	32	11	10	2	3	5	3
All teachers	32	16	13	14	7	8	7	5	4	3

Sample: All teachers in probability sample.

“Frequent Use” defined as students in any of the teacher’s classes having used that type of software on 10 or more occasions.

■ 25%+

There are only three remaining combinations of subject and penetration of frequent use: the World Wide Web in computer education classes, and skills-practice software and CD-ROM software among elementary teachers.⁸ For many other combinations where it is reasonable to think that a given type of software ought to be relevant to learning in a particular subject, we find that fewer than 10% of the teachers of that subject actually have students use that type of software on a frequent basis—for example, spreadsheets in math instruction (4% of all secondary math teachers use it in 10 or more lessons), simulations in science (5%), presentation software in English (4%), multimedia authoring software in social studies (6%), and electronic mail in business education (5%). Clearly, there are large gaps between the potential penetration of many

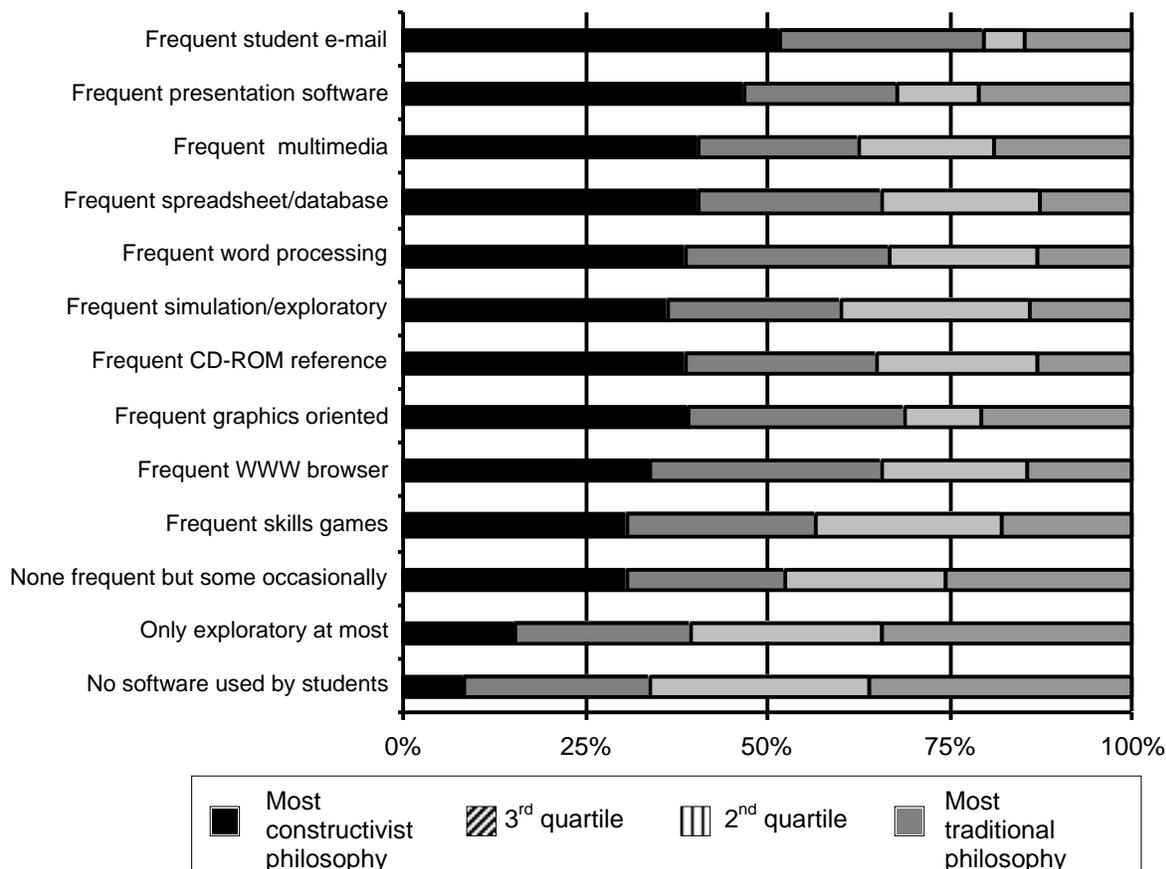
types of software in academic classes and the current proportion of teachers who are actually making use of that software in their classes. With overall patterns of software use like these numbers suggest, Cuban's major claim is certainly not disproved. Frequent use of most computer applications is still a minority teaching practice.

Constructivist Philosophy and Teachers' Frequent Use of Computers with Students

But what of the minority of teachers who *do* make substantial use of different types of software as part of the way they orchestrate student activity during their class time. Do users of only *some* types of software stand out as being constructivist, or are *most* types of software use associated with having a constructivist philosophy?⁹ And how different in philosophy, overall, do these teachers look from the "average" teacher who might have her students use software only occasionally?

Our data suggest that teachers of academic subjects, both elementary and secondary, who use *most* types of software on a frequent basis have consistently more constructivist philosophies than the average teacher. Electronic mail assigning-teachers (that is, the 3% of academic subject teachers who have students use electronic mail on a regular basis) and the almost as small percentage of teachers whose students often use presentation software like Powerpoint (4%) have the most constructivist philosophies of all, with roughly half of them being in the "high constructivist" quartile of teachers, as shown in Figure 9.¹⁰ But, in fact, frequent users of *most* types of software are more constructivist in philosophy than more typical teachers are. All categories of frequent software-users are except those who use *only* skill games frequently. Even skill games users are more constructivist than average if the games are part of a practice that uses other types of software frequently as well. The teachers 3rd-ranked in terms of constructivist philosophy (the 5% who are frequent users of multimedia authoring software) and the 9th-ranked category (the 13% who assign students to do Web work frequently) are closer in philosophy to one another than either is to the larger number of teachers who only occasionally have students use computers. Again, Cuban appears to be correct that technology integration has been accomplished by a relatively small group of academic subject-matter teachers who are significantly different than their peers in terms of teaching philosophy.

Figure 9
Frequent Use of Software (In 10+ Lessons)
by Teaching Philosophy



Sample: Probability sample; academic secondary and elementary teachers only.

When Favorable Conditions are in Place: Compatible Philosophy, Access, and Expertise

If the teachers whose students use software frequently have substantially more constructivist philosophies than most teachers, does it follow that *most* constructivist teachers are computer users? Our data show that, by itself, a constructivist philosophy raises the chance that an academic subject-matter teacher will use many types of software frequently with students, but rarely is a compatible philosophy itself sufficient to boost a majority of teachers into assigning a certain type of computer work frequently. For example, consider middle and high school science teachers. Of *all* science teachers, only 5% reported having students use *simulations or exploratory environments* in at least 10 lessons during the year (shown previously in Table 3). Among the most constructivist quartile of teachers, proportionally twice as many did, but that is still only 10% of the science teachers in that group (see Table 4). In addition, overall, 24% of science teachers had students use *word processing* frequently, but 39% of the high-constructivist science teachers did—nearly two out of every five, but still not a majority. To take another

example, in social studies, no type of software was used frequently by at least one-fourth of all social studies teachers (shown in Table 3). For the high-constructivist social studies teachers, though, three types of software had that level of penetration—word processing, CD-ROM reference materials, and World Wide Web browsers. Nevertheless, the boost was modest, at best; none of those types of software involved even one-third of the high-constructivist social studies teachers on a frequent basis. The only type of software to be used frequently by a majority of high-constructivist teachers was word processing, by elementary grade teachers (55%; see Table 4). In sum, having a compatible teaching philosophy makes frequent use of computers more likely, but by itself is insufficient to make frequent computer use a modal teaching practice.

Table 4
Percent of High Constructivist Teachers (Academic Subjects Only)
Reporting Frequent Computer Use

	Word Proc.	CD-ROM	World Wide Web	Skill practice games	Simulations/ Exploratory Environments	Graphics	Spread-sheets/ Database	Prese-ntation	Multi-media	E-mail
English	49	15	22	6	2	13	3	14	5	7
Science	39	23	24	7	10	7	12	10	3	8
Math	11	4	6	9	8	3	4	2	2	3
Social Studies	28	28	25	8	11	6	9	8	3	11
Elementary	55	35	14	31	14	12	3	6	9	5
All Teachers of Academic Subjects	42	21	19	13	10	11	8	10	6	6

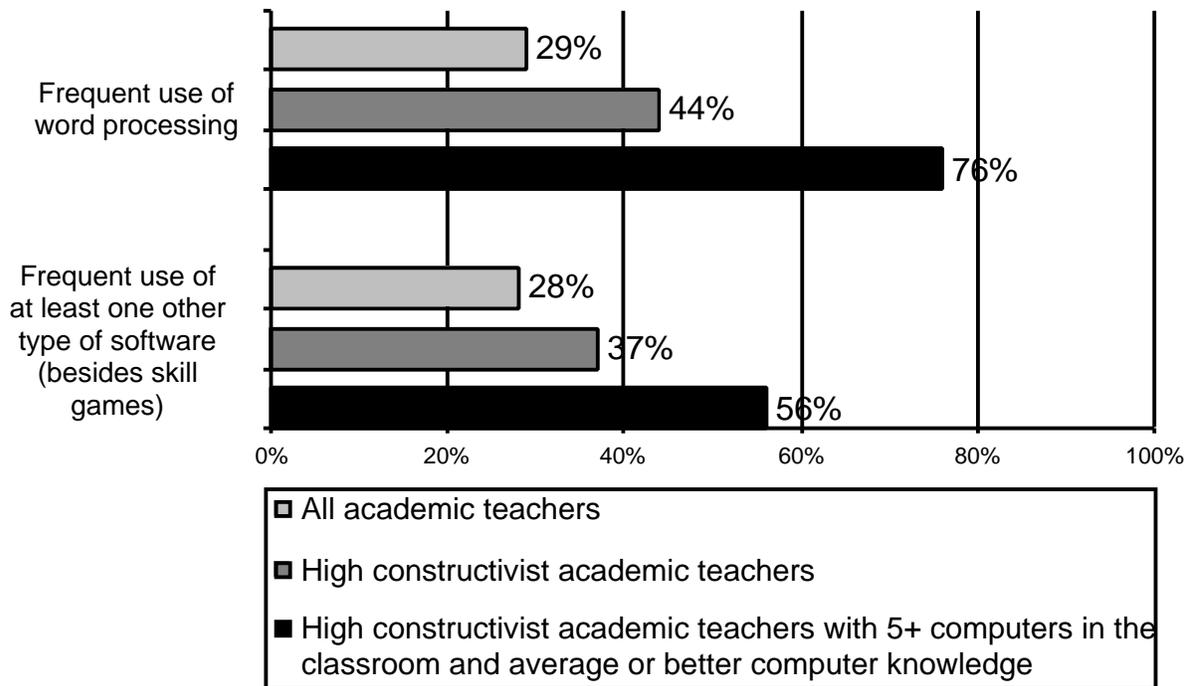
Sample: All academic teachers in probability and purposive samples.

“Frequent Use” defined as students in any of the teacher’s classes having used that type of software on 10 or more occasions.

■ 25%+

However, when we add in two other facilitating conditions—convenient access to a cluster of computers and the teacher having at least average levels of computer knowledge—the story changes. For this analysis, we have to combine teachers of the various academic secondary and elementary subjects together because otherwise the number of survey respondents to be analyzed becomes too small. We present data regarding the use of two categories of software: (1) word processing, because it so clearly dominates frequent computer use; and (2) any other type of software besides skill games, the latter being excluded because of the clearly distinct pedagogical approach it reflects. Figure 10 shows the percentage of teachers reporting frequent use of these two categories of software according to progressively more enabling conditions. Overall, 29% of all academic secondary and elementary teachers reported using word processing frequently and 28% reported using at least one other type of software frequently. When we restrict ourselves to the high constructivist quartile of teachers from the same subjects, the percentages rise somewhat, to 44% and 37% respectively.¹¹ However, when we specify the other two important facilitating conditions—that the teacher has a cluster of 5 or more computers available in her own classroom and also has at least average computer skill and breadth of professional computer use—the percentages climb to well over a majority. More than three-fourths of such teachers (76%) had students use word processing in at least 10 lessons during the year, and 56% had them use some other type of software that often.¹²

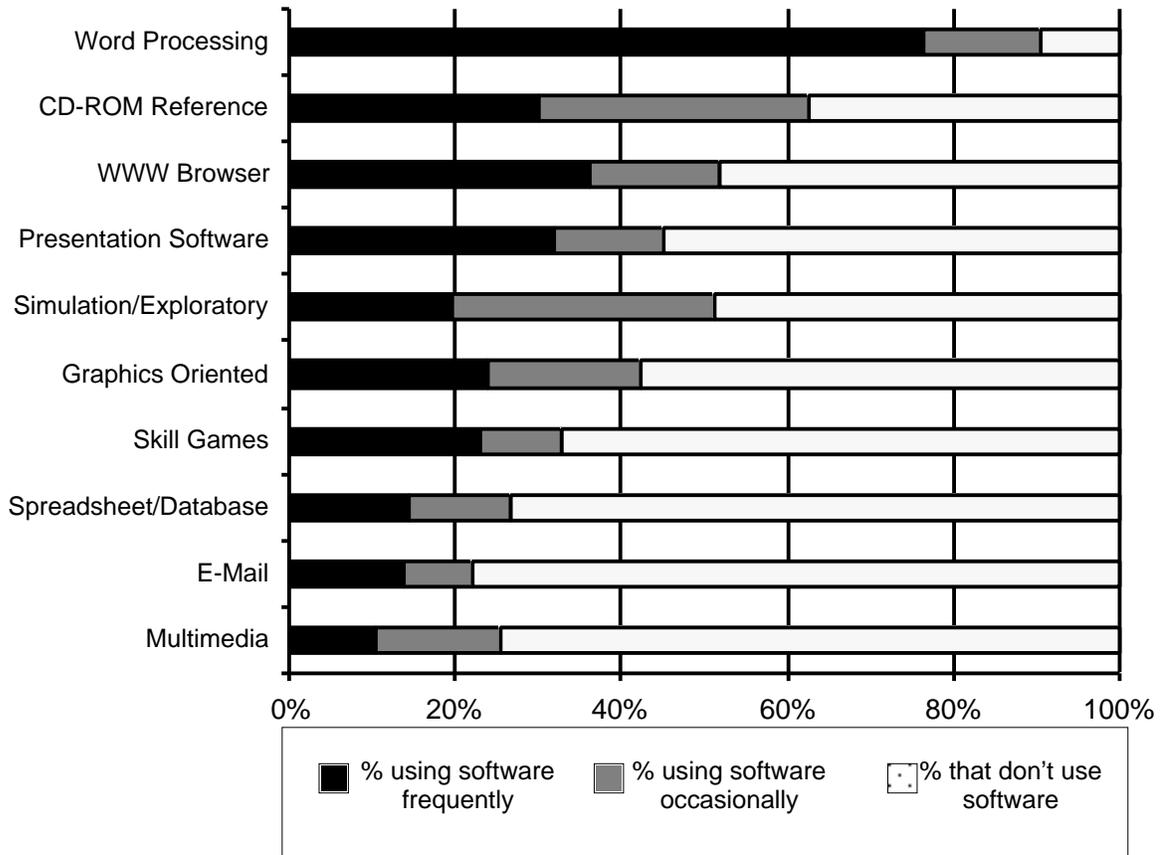
Figure 10
Frequent Use of Software by Facilitating Condition



Sample: All academic teachers in probability and purposive samples.

Figure 11 shows that for this group of academic subject matter teachers—that is, those with a highly constructivist philosophy who also have a cluster of computers in their classroom and at least average computer competencies and professional use themselves—not only did three-fourths have students use word processing frequently, but about one-third had students use presentation software frequently, one-third had students use the Web in 10 different lessons, a majority had students use CD-ROM reference materials on at least 3 occasions during the year, and similarly a majority had students use exploratory or simulation software at least that often. For this group, skill-based software is used less often than any of *those* applications, but it is still more common than spreadsheet work, student e-mail, or student authoring of multimedia documents.

Figure 11
Software Use Among The Most Constructivist Quartile of Secondary Academic and Elementary Teachers Who Have 5+ Computers in the Classroom and Average or Better Computer Knowledge



Sample: Probability and purposive samples; as defined in table title.

The statistics in the previous paragraph are *critical*. They demonstrate that under the right conditions, teachers of academic subjects will make substantial use of a wide range of computer software, going well beyond routine drill-and-practice. Nevertheless, not every computer application has yet found its niche in the practice of academic subject teachers, even when many of the facilitating conditions are in place.

Outcomes of Constructivist Uses of Computers: Effects on Student Out-of-Class Effort

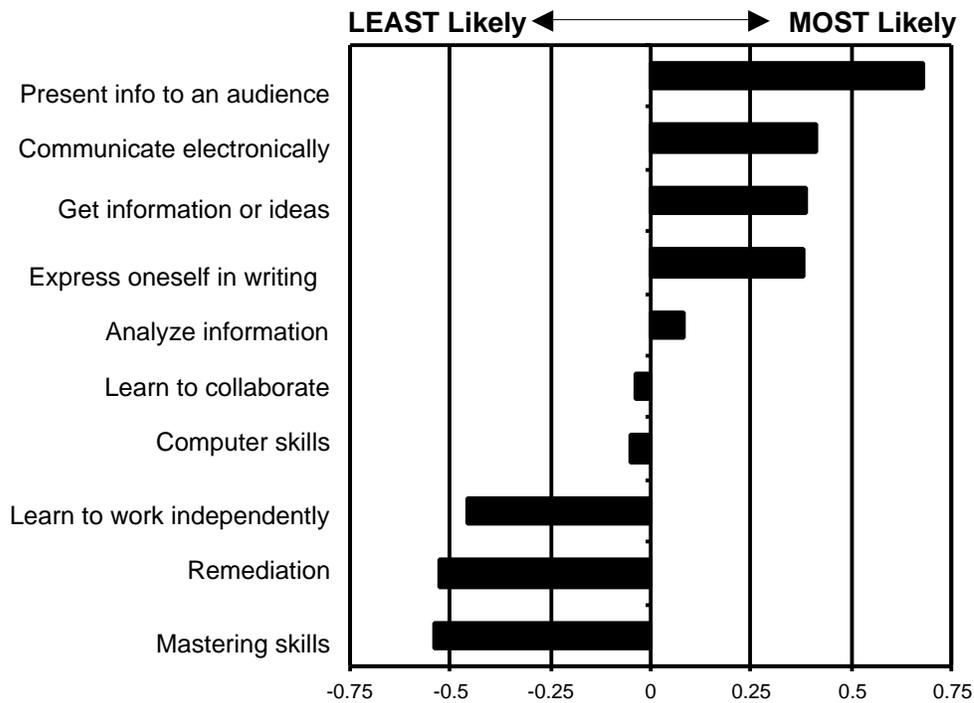
Demonstrating that under propitious conditions, a large fraction of teachers of academic subjects are having their students use a variety of computer applications does not necessarily prove that students are better off for this as a result. Our Teaching, Learning, and Computing survey did focus more on the “teaching” and “computing” aspects of computer use in schools than on the

“learning” part, but we do have some modest empirical evidence on one interesting student outcome—students’ use of computers for doing class work on their own time.

Why should simply measuring student out-of-class-time use of computers for schoolwork be considered an important outcome? For one thing, although public evaluation of schools tends to focus on the substantive facts and skills that students are being taught, a widely acknowledged goal of schooling is to foster in students a disposition to undertake learning activities on their own initiative, over the long-term. If students take initiative in doing academic work outside of the time they are being directly supervised in class, the strategies that teachers use to increase the likelihood of that happening may be as important as what they do to help students learn more during class time. Although we have a very weak measure of the out-of-class computer-use outcome—teachers’ own estimates of the proportion of their students who use computers for class work at other times during the school day and the proportion that do so while at home—we can report some interesting findings related to teachers’ different patterns of computer use.

We found that computer-using teachers who prioritize certain objectives for their students’ computer use are much more likely than those emphasizing other objectives to report that their students use computers for class assignments during other times of the day and week. Figure 12 shows the general result¹³ and highlights four outcomes associated with greater than average out-of-class-time work and three outcomes associated with below-average levels. The teachers who report by far the highest proportion of students doing computer work outside of class were those whose primary objectives were having students *present information to an audience*. Asking students to prepare an oral talk before an audience seems to generate a strong motivation for students to be deeply engaged in their schoolwork—enough to keep them working after school or even at lunch. The other three objectives whose advocates reported more than average out-of-class computer work being done were these: (a) having students communicate electronically with other people, (b) having them obtain information or ideas from computer sources, and (c) having them express themselves in writing. When we distinguished the extra time spent by students while they were still at school from their efforts at home, it was clearly the time at-home which was being affected by teachers emphasizing the objectives of communications (i.e., through e-mail), information acquisition (Web), and writing (word processing). Not surprisingly, e-mail, Web browsers, and word processing programs, along with games, are the most common software applications available to students on their home computers. In contrast, where students followed their teachers’ aspirations for them to prepare presentations to an audience by spending extra effort, disproportionately they did so while at school. This may be due to many assignments like this requiring collaboration among classmates, and the convenience of being able to get together as a group while at school.

Figure 12
Which Teachers Report Student Use Computers for Class Work
Outside of Class Time? (Effect Sizes)



Sample: Probability sample; questionnaire versions 1 and 2; teachers who used computers with students in their selected class.

The fact that at-home differences in students' out-of-class efforts (i.e., for teachers with different objectives) were generally greater than at-school differences is a reminder of the important role that private access to computing facilities plays in some of the types of computer work which may be most beneficial for students. We did not have information on the presence of home computers among the students of each teacher, but we did analyze the effects of teacher objectives on out-of-class effort after taking into account the socio-economic-status (SES) of the school's students and the student ability levels reported by teachers, two factors that are closely associated with home computer access.¹⁴ Table 5 shows that although class ability and school socio-economic-status are each strongly associated with student out-of-class computer work (and more strongly with at-home effort than at-school effort), teacher objectives still have effects that are independent of student characteristics. Thus, teachers whose objectives for student computer work were skills-related or "learning to work independently" (i.e., not bothering other students) reported less out-of-class computer work than teachers having other objectives, even after controlling statistically for school SES and class ability level. This was particularly true for students' doing computer work for class while at home. Similarly, at the positive end, the same objectives shown in Figure 12 remain important. In particular, teachers with presentation objectives for their students' computer work have more students doing computer work on their own time at school, and teachers with writing, information gathering, and electronic communications objectives have students who do more computer for class while at home, even after socio-economic and scholastic achievement factors are considered.¹⁵

Table 5
Teachers' Objectives For Student Computer Use Related To Fraction of Students Reported To Use Computers For Classwork Outside of Class Time

	Use in school, outside of class	Use outside of school	All non-class time use
Correlation of non-class time use with...			
Average Ability of Students in Class (teacher estimate)	+0.21	+0.34	+0.32
School Socio-Economic Status Multiple correlation coefficient (control variables only; includes school level also)	+0.14	+0.38	+0.30
	.22	.44	.38
Standardized regression coefficients controlling on class ability, SES, & school level (elem., MS, HS). (each objective in separate equation)			
Present Information to an Audience	+0.22	+0.14	+0.21
Express Oneself in Writing	+0.10	+0.20	+0.17
Get Information and Ideas	+0.06	+0.21	+0.16
Communicate Electronically	-0.03	+0.17	+0.08
Learn to Work Collaboratively	+0.02	-0.01	+0.00
Improve Computer Skills	-0.01	-0.03	-0.02
Analyze Information	-0.03	-0.08	-0.04
Remediate Skills	-0.09	-0.16	-0.15
Learn to Work Independently	-0.05	-0.21	-0.15
Master Skills Taught (reinforcement)	-0.16	-0.20	-0.22

Sample: Probability sample only; teachers who used computers with their selected class.

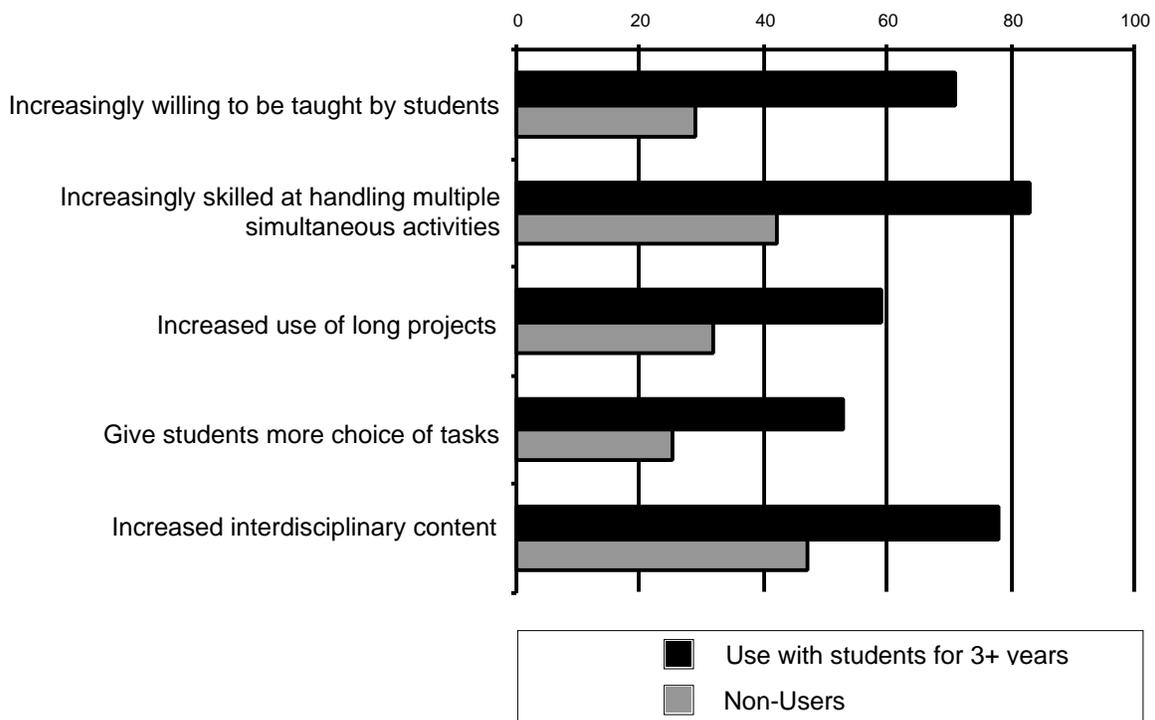
Effects of Computer Use on Teachers: Changing Towards a Constructivist Practice

Although most discussion of the outcomes of teachers' use of computers in instruction focuses on *student* outcomes, it is important to consider how teachers' experiences with using computers might be changing their teaching practice as a whole. (The paper by Thompson, et al (2000), in this set also considers this possibility.) In particular, examination of our survey data showed us that teachers are much more constructivist in philosophy than they typically are in actual practice—no doubt the result of the many difficulties involved in doing constructivist sorts of things; e.g., having students' interests affect the topics of their classwork, orchestrating classes so that multiple activities can occur simultaneously, or having students do serious group work including engaging one another in authentic exchanges of ideas and opinions.

In previous research, Becker and Ravitz (1999) proposed that when circumstances were favorable, sustained and thoughtful use of computers as learning resources could actually help teachers implement a teaching practice that was as constructivist as their teaching philosophy would permit. In a study of 441 teachers at 152 schools of the National School Network, we

found that teachers at these schools who used computers with students regularly over a three year period were roughly twice as likely to report having made a number of constructivist-oriented changes in their teaching practice as were teachers who did not use computers with their students. In particular, more than 70% reported they were now more willing “to be taught by students” than three years previously, compared to fewer than 30% among non-computer-assigning teachers. Similarly, they were much more likely to report increased skill in conducting multiple parallel activities during class time, engaging students in long projects, and giving students choices in the tasks they undertook. (See Figure 13.) In addition, supporting the argument made earlier, teachers were twice as likely to report seeing students take more initiative outside of class time. It is important to note that the schools of the National School Network were not “typical” schools. First, they had significantly more technology per-capita than average. Second, they were schools where leadership had developed strong associations with outside organizations supporting educational reform through the use of computer technology, organizations such as museums, university research projects, and private businesses. And third, the schools provided a climate supportive of curricular and instructional change.

Figure 13
Computer-Using Teachers Reported More Changes In Their Teaching Practice
In The Past 3 Years Than Non-Users
National School Network Survey, Spring, 1997



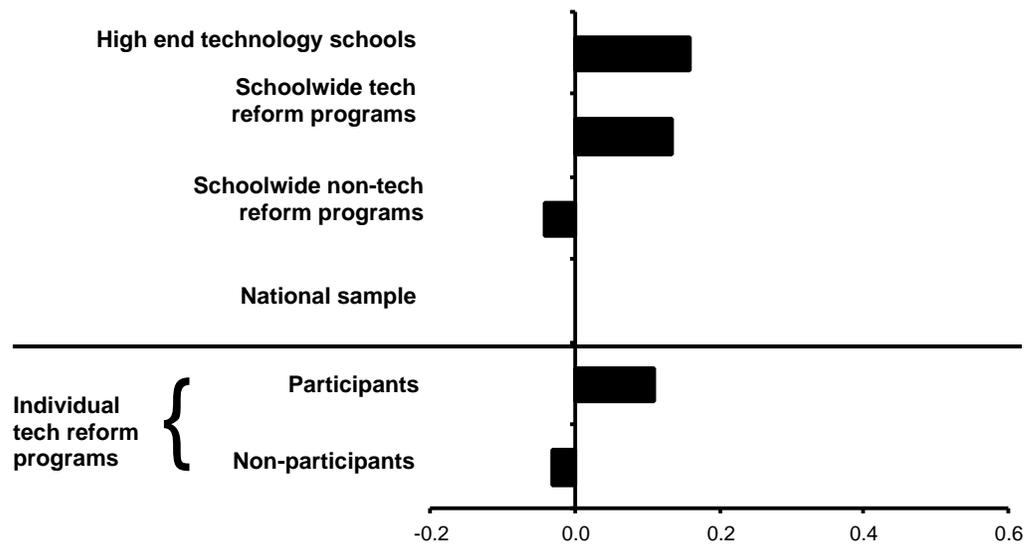
In the Teaching, Learning, and Computing survey, we have explored similar relationships between teachers' computer use and changes in instructional practices towards a more constructivist approach to teaching. We have found, for example, that across all schools (as

opposed to the relatively homogeneous schools of the National School Network) teachers who were *the least* knowledgeable about computers were also less likely than other teachers to report having become more constructivist over the previous three years. (However, no differences have been found between teachers who were “average” and those who were “high” on our index of computer knowledge.) On the other hand, constructivist change seems to have occurred more often than typically among teachers who used a large variety of software in their teaching practice, those who used the World Wide Web a great deal in their teaching, and those whose primary objectives for computer use were having students learn to work collaboratively or to write better.

Those are results that generalize to all schools. However, the theory proposed in the National School Network study was that the schoolwide environment with respect to technology and instructional reform is a conditioning variable (i.e., either facilitates or impedes) the effects of computer use on pedagogical practice more generally found. That hypothesis is supported by our initial analysis of the several different independently drawn samples in the Teaching, Learning, and Computing survey.

The TLC survey, in addition to the national probability sample of schools, included several different “purposive” samples—schools selected either individually or sampled from larger sets of schools specifically because of either having a large presence of leading-edge computer technology or being closely involved with programs of instructional reform, including 50 of the major national and regional reform programs (e.g., Coalition of Essential Schools, Accelerated Schools, two NSF systemic reform programs). We are finding that teachers in three groups of schools seem to have made more changes towards a constructivist teaching practice than teachers in the national probability sample: (a) teachers in the leading-edge schools with high levels of technology per capita, (b) teachers in schools with both a schoolwide emphasis on instructional reform *and* an emphasis on using computer technology in those reforms, and (c) participating teachers (and *only* participating teachers) in schools where one or two such teachers are involved in an externally organized program of technology-based instructional reform. Significantly, one group of schools does *not* show greater movement towards constructivist practices by their teachers—schoolwide reform programs that *do not* emphasize computer technology. Teachers in those schools reported, at best, the same pattern of pedagogical change as did the national probability sample of teachers. (See Figure 14.)

Figure 14
Constructivist Change in Teaching Compared to the National Sample



Sample: All teachers in probability and purposive samples.

These findings suggest that both *teacher-level* characteristics (i.e., how much they use certain computer applications and their objectives for that use) and *school-level* characteristics, such as the central role of computers in the school's character, help teachers move towards a constructivist pedagogy.

Conclusion

In response to Cuban's projection that computers are destined to play a minor role in student learning of academic subjects in elementary and secondary schools, this paper has presented an examination of related evidence.

On the issue of whether computers are generally a central vehicle of instructional activities in classrooms, the data suggest that Cuban remains correct at this time. Although a substantial fraction of teachers are having students do word processing during class time, most in-class use of computers occurs as part of separate skills-based instruction about computers, in occupationally-oriented courses such as business and vocational education, and as one of many explorations of different learning modalities that occur in the 6-hour-long days of self-contained elementary classes.

We have also found that the teachers who have students use non-skills-oriented computer software in academic classes have fairly distinctive teaching philosophies, being disproportionately supportive of constructivist pedagogies such as developing student responsibility for selecting and carrying out learning tasks, emphasizing group work involving discourse, and the use of projects, products, and performances for outside audiences.

However, the TLC data also suggests that when constructivist-oriented teachers in addition have sufficient resources in their classroom (i.e., clusters of 5 or more computers in a typical sized class) and have come to have a reasonable level of experience and skill in using computers themselves, a *majority* of such teachers will have their students make active and regular use of computers during their class period. That use will be principally word processing but will typically involve at least one other type of software as well, most often either CD-ROM or Internet-based information retrieval or exploratory simulation software. Other facilitating factors, such as extending the secondary classroom period from 50 minutes to significantly longer blocks of time and not only removing curriculum coverage mandates from teachers but encouraging them to teach fewer subjects in depth also can increase the number of teachers who make frequent use of computers in their plans for student class work.

Furthermore, we found that when teachers emphasize communication and information-oriented objectives for their students' software use (i.e., publishing for an audience, communicating electronically, writing, and finding information), they expand students' academic effort from class time to free time, suggesting that a non-skill, tool-application focus to using computers in class results in greater student engagement in their academic assignments.

Finally, our data suggest that certain approaches to using computer technology (i.e., broad use of different types of software, an emphasis on student writing and on exploiting Web-based sources of information) as well as a schoolwide emphasis on technology, particularly in the context of supporting instructional reform, are forces that helps teachers realize significant changes in their pedagogy more generally, enabling them to put into practice a pedagogy that is more constructivist and more attuned with their teaching philosophy.

Thus, in a certain sense Cuban is correct—computers have *not* transformed the teaching practices of a majority of teachers, particularly teachers of secondary academic subjects. However, under the right conditions—where teachers are personally comfortable and at least moderately skilled in using computers themselves, where the school's daily class schedule permits allocating time for students to use computers as part of class assignments, where enough equipment is available and convenient to permit computer activities to flow seamlessly alongside other learning tasks, and where teachers' personal philosophies support a student-centered, constructivist pedagogy that incorporates collaborative projects defined partly by student interest—computers are clearly becoming a valuable and well-functioning instructional tool.

Moreover, where implemented in a responsible way, that tool is having an impact, not only on students' performances in class, but on their academic effort outside of class as well. In addition, many teachers, emphasizing the use of computers for student outcomes such as improved writing and research competencies, along with other teachers who are lucky enough to work in school environments where computer technology and instructional reform are cultural values, are being helped by technology to accomplish the goals of most current instructional reform efforts. They are creating classrooms where both they and their students are engaged in authentic efforts at increasing academic understanding rather than going through the more superficial traditional practice of schooling: surface coverage of a massive and externally mandated curriculum, even when anointed under a label of "standards-based reform."

References

- Becker, H. J. (2000). Who's Wired and Who's Not. *The Future of Children*. Center for the Future of Children, The David and Lucille Packard Foundation. 10:1 (Spring).
- Becker, H. J. and Anderson, R. E. (1998). Validating Self-Report Measures of the 'Constructivism' of Teachers' Beliefs and Practices." Paper presented at the 1998 meetings of the American Educational Research Association.
- Becker, H. J. and Ravitz, J. L. (1999). The Influence of Computer and Internet Use on Teachers' Pedagogical Practices and Perceptions. *Journal of Research on Computing in Education*. 31 (4), Summer, pp. 356-384.
- Becker, H. J., Ravitz, J. L., and Wong, Y-T (1999). Teacher and Teacher-Directed Student Use of Computers and Software. Teaching, Learning, and Computing: 1998 National Survey, Report 3. Center for Research on Information Technology and Organizations, University of California, Irvine.
- Cuban, L. (1986). *Teachers and Machines: The Classroom Use of Technology Since 1920*. New York: Teachers College Press.
- Cuban, L. (2000). So Much High-Tech Money Invested, So Little Use And Change In Practice: How Come? Paper prepared for the Council of Chief State School Officers' annual Technology Leadership Conference. Washington, D.C. (January).
- Dede, C. (2000). Implications of Emerging Information Technologies for States' Education Policies. Paper prepared for the Council of Chief State School Officers' annual Technology Leadership Conference. Washington, D.C. (January).
- Means, B. (2000). Accountability in Preparing Teachers to Use Technology. Paper prepared for the Council of Chief State School Officers' annual Technology Leadership Conference. Washington, D.C. (January).
- Perkins, D. (1998). What is Understanding. In Wiske, Martha Stone, ed., *Teaching for Understanding: Linking Research with Practice*. San Francisco: Jossey-Bass.
- Thompson, A. D., Schmidt, D. A., and Stewart, E. B. (2000). Technology Collaborates for Simultaneous Renewal in K-12 Schools and Teacher Education Programs. Paper prepared for the Council of Chief State School Officers' annual Technology Leadership Conference. Washington, D.C. (January).

Footnotes

¹ Except where indicated by text or footnotes, statistical results are based solely on the weighted nationally representative sample of teachers and schools. For more details on the sampling and study methodology, see Becker, Ravitz, and Wong (1999), Appendix B.

² Just a few computers in a classroom would not seem to make much sense. However, numbers like 5, 6, or 8 can be used quite efficiently for many kinds of classroom activity plans.

³ Although 18% of the survey respondents reported publishing on the World Wide Web, that estimate does seem inordinately high, given other data reported in the survey. Some frequency of misunderstanding of the survey question is probably responsible.

⁴ Means (2000), in her paper in this series, provides examples of how professional computer knowledge does not *always* translate into effective pedagogy with the same software.

⁵ In this survey measurement context, correlations above .20 generally indicate differences worth paying attention to; correlations above .30 are “substantial”; and those above .40 would be considered very large. The table excludes teachers who don’t use computers with their classes at all, but includes teachers from the special samples of schools in reform programs or with high-end technology presence in addition to the nationally representative sample.

⁶ The validity of teachers’ philosophical statements is somewhat problematic. Like reports of their actual practice, they may be subject to “social desirability” effects—i.e., wanting to give an answer perceived as desirable by others. However, prior to this national survey, we validated a set of statements about teaching philosophy through extensive interviews with 72 teachers in 24 schools in three parts of the U.S. The items selected (or modified) for this study were the items that correlated most strongly with the interviewers’ judgments about the teachers’ actual teaching philosophies. See Becker and Anderson (1998). Moreover, the primary use of the philosophy items in this study, however, is not to determine on an absolute scale how constructivist teachers are but whether those who are relatively more constructivist in philosophy than others respond more strongly to the option of using computers in their teaching.

⁷ Figure 8 uses a continuous measure of teaching philosophy, from most transmission-oriented to most constructivist, rather than the quartiles shown in Figure 6.

⁸ The CD-ROM item was described as CD-ROM *Reference* software but probably many teachers interpreted the survey question to include skills-games and exploratory software on CD-ROMs.

⁹ Chris Dede, in his paper in this set (Dede, 2000), discusses how a wide range of software provides opportunities for students to engage in knowledge construction activities.

¹⁰ The analysis in this paragraph concerns teachers of secondary academic subjects and elementary teachers. It omits teachers of applied secondary subjects like computer education, business education, vocational education and fine arts.

¹¹ Comparison based on probability plus purposive sample data. These two groups differ very little on gross measures; however, the purposive sample is needed in these comparisons because the restriction to high constructivist philosophy teachers limits the number of teachers available by subject.

¹² Teacher reports of frequent computer use by their students in class may be subject to upward bias due to the same social desirability factor noted in an earlier footnote with respect to reports of constructivist teaching philosophies. However, the data show *huge differences* in frequent student computer use between *all* teachers and teachers whose conditions are favorable (i.e., philosophy, computer knowledge, etc.). If social desirability was inflating teacher reports of frequent computer use substantially, we would not see such low percentages for all teachers combined with such high percentages for teachers with facilitating conditions. Moreover, random error in the measurement of the facilitating conditions (e.g., ‘adequate computer knowledge’ is measured by a simple index of self-reports) tends to diminish the size of differences found. This would suggest that the true percentage of frequent users in the “all facilitating conditions present” category is even higher than reported.

¹³ The measure used in Figure 12 is the effect size between teachers who selected a given objective as primary versus those who did not. The effect size is the difference in the mean responses by the two groups of teachers divided by the standard deviation of teacher responses on the measure. The two items averaged in the measure (computer use at other times of the day while at school; and computer use at home) were each scored on a scale from 1 to 5 representing the poles of “none or few” students doing this on at least several occasions to “all students” doing this.

¹⁴ See Becker (2000) for evidence on the relationship between student SES and basic home computer access as well

as the level of functionality of home computers owned by families of students of different economic and educational circumstances.

¹⁵ It is also possible that weak measurement of control variables—class SES was measured by school-level SES indicators and student ability was estimated by teachers, and home presence of computers was not measured directly—might leave us to ascribe some variation to teacher objectives that ought to be ascribed to student background factors. However, the SES and school level controls reduced the associations for objectives only to a small degree.