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# High Access and Low Use of Technologies in High School Classrooms: Explaining an Apparent Paradox

Larry Cuban
*Stanford University*
Heather Kirkpatrick
*Aspire Public Schools*
Craig Peck
*Stanford University*

*Most policy makers, corporate executives, practitioners, and parents assume that wiring schools, buying hardware and software, and distributing the equipment throughout will lead to abundant classroom use by teachers and students and improved teaching and learning. This article examines these assumptions in two high schools located in the heart of technological progress, Northern California's Silicon Valley. Our qualitative methodology included interviews with teachers, students, and administrators, classroom observations, review of school documents, and surveys of both teachers and students in the two high schools. We found that access to equipment and software seldom led to widespread teacher and student use. Most teachers were occasional users or nonusers. When they used computers for classroom work, more often than not their use sustained rather than altered existing patterns of teaching practice. We offer two interrelated explanations for these challenges to the dominant assumptions that guide present technological policy making.*

LARRY CUBAN is Professor Emeritus of Education at Stanford University, Stanford, CA 94305. His specializations are history of teaching, curriculum, technology, school reform, urban administration, and leadership.

HEATHER KIRKPATRICK is Director of Secondary Schools, Aspire Public Schools, 1564 Laurel Street, San Carlos, CA 94070. Her specializations are high school reform, school governance, and charter schools.

CRAIG PECK is Acting Assistant Professor of Education, Stanford University, 5285 Diamond Heights Boulevard 115, San Francisco, CA 94131. His specializations are history of education and educational technology.

Shelley, an 11th grader in Alison Piro's Humanities class, is standing on a raised platform in the middle of the classroom, surrounded by students seated at their group tables. The classroom lights are turned off and the shades are drawn. The only light in the room comes from the overhead projector which Alison Piro positions in such a way that it serves as a spotlight on Shelley. With these words, "The freedom we should demand . . . " Shelley begins her speech as ex-slave Frederick Douglass.[1]

These few moments in Alison Piro's classroom capture the essence of Piro's teaching—dramatic, diligently planned, and even innovative in its use of technology (albeit in this case a low-tech machine). The environment is warm and safe and conducive to students' performances. Whether it is a literary reading, a film produced by students, a piece of art, or a slide show, performance is a central part of Piro's pedagogy, a strategy she believes allows students to demonstrate their comprehension of concepts and themes they have read and discussed. In Shelley's case, it is the reworking of ideas from Frederick Douglass's autobiography into a powerful speech on the rights of freed men. Piro's innovative, if unusual, use of the overhead projector as spotlight illustrates her innovative approach to technology in the classroom in general.

With 5 years of teaching experience, Alison Piro teaches two periods of an 11th-grade interdisciplinary Humanities class a day and uses the rest of the day to help create a standards-based curriculum for ninth graders. She co-plans and coordinates the block schedule Humanities class with Alan Bloom. He takes the lead on the Social Studies curriculum and she takes the lead on the English curriculum, although both agree that theirs is entirely a team effort. Each class has 32 students.

Piro is a leader in integrating the English and Social Studies curriculum as well as a leader in integrating computers into that curriculum. She believes in the power of technology as a teaching and learning tool and wants to tap its potential. "It's how you use the tool," Piro says. "If we are only using it to word process then we may as well have typewriters."[2]

In Piro's Humanities class, students use the Internet to do research and word processing programs to write passages that accompany visual presentations such as slide shows done on Claris Works and films made with AVID software. She expects students to "conceptualize and actualize" ideas using technology as their medium. For example, after reading several works of utopian literature, groups of students had to create their own utopias and make a film (using AVID software) that would "sell" their utopias to their audience, their classmates.[3]

Piro's students use computers about eight times a month. Typically, students work in pairs or groups on projects that take up to 2 weeks. Piro acts as the facilitator, moving from group to group to support and challenge them as they proceed.

> Our technology use tends to span several days. For instance, when we were doing our Utopian Society project we were in the media center, using butcher paper, pencils, and pens for about three days before we ever got to the technology. Then we spent a whole day researching images on laser disc, video and the Internet. Then we spent a whole other three days and a Saturday working with AVID. So there are levels of technology use that get us to the point where we are actually manipulating the hardware and software.





Computers, however, are not appropriate for all projects. According to Piro, computer use depends on the instructor's teaching and learning goals. Piro admits that there have been times when she chose incorrectly. An essay, for example, may have been a more appropriate assignment than a computer project. She is a thoughtful, determined teacher who carefully considers what tool—an essay, a computerized slide show, a short answer exam, a piece of art, a digitized movie, a research project using the Internet—is most appropriate for engaging students.

We studied teachers in two Silicon Valley high schools who have integrated technology into their daily instruction. According to national surveys and reports, technology leaders like Piro comprise a fraction of school faculties; they are the early adopters of technological innovations. These teachers differ from the majority of their colleagues both in the frequency with which they use computers in their classrooms and in the ways they teach. Thus, we face an anomaly (Anderson & Ronnkvist, 1998; Becker, Ravitz, & Wong, 1999a; Sandholtz, Ringstaff, & Dwyer, 1996; Schofield, 1995).

After almost two decades of intense promotion of information technologies by business leaders, policy makers, and parents, most teachers and students now have far more access to machines and software both in school and at home than ever before. Yet, nationally, most teachers and students are occasional to rare users (at least once a month) or they are nonusers of these machines in classrooms for instruction. Furthermore, when teachers do use computers for instruction, another discrepancy arises. When teachers adopt technological innovations, these changes maintain rather than alter existing classroom practices (Mehan, 1989; National Educational Assessment Program, 1996; Schofield, 1995).

These unexpected outcomes lead to the following questions: (1) With abundant access to information technologies, did the national patterns of infrequent and limited teacher usage of computers emerge at the two high schools? If so, why? (2) Did teachers in the two high schools who used computers in their classrooms for instruction typically maintain existing practices? If so, why?

## School Reform and Technology Use in Schools for Instruction

The history of school reform aimed at substantially altering teachers' routine classroom practices is replete with school boards and superintendents adopting ambitious designs that often ended in little classroom change, utter disappointment, and bitter recriminations. Zealous reformers can view past

failures as a challenge or succumb to pessimism. Few of these reforms noted the workplaces within which teachers labored, involved teachers in the design itself, allocated sufficient resources to develop teachers' capacity to implement the desired changes, or provided sustained support to ensure that those changes become part of teachers' daily routines. The history of classroom reform is documented in Cuban (1993), Elmore and McLaughlin (1988), Sarason (1971), Spencer (2000), Tyack and Cuban (1995), and Zilversmit (1993).

Less well known, but equally available, is the history of technological innovations aimed at improving teaching techniques. The design, adoption, and implementation of new technologies also have had a long history that invites little optimism (Cohen, 1987, 1990; Cuban, 1986).

### Frequency of Teacher Use

Fifteen years ago, Cuban (1986) claimed that the majority of U.S. teachers were nonusers of computers in their classrooms, about 1 in 4 were occasional users (at least once a month), and 1 in 10 were serious users (at least one or more times a week). At a time when access to hardware and software was limited, we would expect such minimal use. National data confirmed that claim.[4]

Since the early 1990s, the importance of an information-based economy that requires knowledgeable and technically skilled workers has been promoted in the media and by legislation. Policy makers believe that creating abundant access to new technologies in schools will lead to increased teacher use in classrooms, which will lead to better teaching and learning. At a meeting of Silicon Valley corporate executives (Seipel, 2000), President Clinton put it most explicitly: "Frankly, all the computers and software and Internet connections in the world won't do much good if young people don't understand that access to new technology means . . . access to the new economy (pp. 1, 16). School officials have wired schools, invested in hardware and software, and campaigned to convince teachers to use new technologies in their classrooms. The campaigns, which have produced remarkable access to new technologies, have produced a modest shift from nonusers to occasional users and from occasional users to serious users.[5]

Even with this slight shift in reported classroom use, more than one half of elementary and middle school teachers are nonusers of computers for classroom instruction, about one third are occasional users, and about 1 in 10 is a daily user. In high schools, 2 of 10 teachers are serious users and 4 of 10 use machines at least once a month. Over the last decade, there has been progress among elementary teachers from nonusers to occasional users and from nonuse to occasional and serious use among high school teachers (Means & Olson, 1995; National Educational Assessment Program, 1994, 1996; Schofield, 1995; "Technology Counts," 1997; U.S. Congress, Office of Technology Assistance, 1995).





### Computer Use in the Classroom

Although we need to know how often students turn on computers in school, we also need to determine how they are being used. Teachers and senior high school students report that they use computers mostly for word processing. In eighth-grade math, less than one half of the teachers reported in 1996 that they used computers at all. Of the teachers who did, 18% said they had students do drill and practice on the machines, 13% had students play math games, 13% had students do simulations, and 5% used software to demonstrate new concepts in math. Both supporters and critics of school technology agree that software and hardware are used in limited, even simple ways, often sustaining rather than transforming prevailing instructional practices (National Educational Assessment Program, 1996; Wenglinsky, 1998).

We studied two California high schools, Flatland and Las Montañas, to determine if these claims could be verified in settings where technologies were abundant and strongly advocated by public officials, educators, and parents.

## Method

We spent 7 months during the 1998–1999 school year in two high-tech schools that had enrollments of about 1,900 students (with over 80 teachers) and 1,300 students (with over 60 teachers), respectively. Between October 1998 and April 1999, we interviewed 21 teachers and 26 students in both schools who had volunteered to be part of the study. The participants were users and enthusiasts who were eager for access to more computers in their schools. We shadowed 12 students in both schools as they journeyed through a school day and did the same for 11 teachers at both schools. We also surveyed both faculties at their required monthly meetings; two thirds of the teachers responded in one high school and four fifths in the other. For our student surveys, we selected in each school the period before lunch on a Wednesday and went to every single English class to administer the 10-minute survey; we received surveys from one fourth of one school's entire student body and one third of the other high school's students. School staff provided us with teacher sign-up data from both media centers and computer labs. Finally, we examined accreditation reports, proposals for launching reforms, grants seeking technology funds, and newspaper articles written about the schools. In our selection of students and teachers and, in our use of multiple sources of data, we sought a complete, even positive picture of computer use for instruction.

### The Setting

Stretching along the peninsula from San Francisco to San Jose with its de facto capital at Stanford University, Silicon Valley is home to thousands of computer and Internet companies and is acknowledged throughout the

Table 1
**Two Silicon Valley High Schools**

| Characteristic | Flatland High School | | Las Montañas | |
|---|---|---|---|---|
| Total number of students | 1,854 | | 1,262 | |
| Total teaching staff | 81 | | 60 | |
| Diversity | Students/teachers | | Students/teachers | |
| Latinos | 24% | 18% | 39% | 11% |
| Whites | 40% | 76% | 26% | 83% |
| Asian/Pacific Islander | 32% | 4% | 20% | 2% |
| African American | 3% | 1% | 10% | 2% |
| Native American | 1% | 1% | 1% | 2% |
| Students receiving free/reduced lunch | 27% | | 44% | |
| Limited English proficient students | 14% | | 16% | |
| Combined average SAT scores | 999 | | 1,013 | |
| Graduates planning to attend college and university | College/University | | College/University | |
| | 55% | 30% | 40%[a] | 32% |
| Per-pupil expenditure | $5,178 | | $5,263 | |

[a]1997.

world as the epicenter of the ongoing technology revolution (Kaplan, 1999; Quinn, 1999; Quinn & Lafleur, 1999). With over 1.5 million people in the Valley, 1 of every 6 people work in the multibillion dollar microelectronics industry. Nestled in two Silicon Valley neighborhoods filled with modest to affluent homes and located eight miles apart, are the Flatland and Las Montañas high schools.

The two Silicon Valley suburban high schools had similar per-pupil expenditures, culturally and socioeconomically diverse student populations, and students with middle-range SAT scores who aspire to higher education (Table 1). Are they also similar in making available to students and teachers the new information technologies?

## Access to Computers and Other Technologies

The common metric to judge public school response to technological changes is the ratio of students to computers. The calculation is done by dividing a school's total number of students by its total number of computers. Since the early 1980s, acquiring more machines to reduce the ratio has been the primary measure of a school's technological success. Nationally, the figures show sharp reductions. From 92 students per computer in public





Table 2
**Students Per Computer by Location, 1998–1999**

| Computer access | Nation | California | Flatland | Las Montañas |
|---|---|---|---|---|
| Schoolwide | 6 | 6 | 5 | 4 |
| Classroom | 17 | 22 | 22 | 17 |
| Lab | 21 | 31 | 8 | 12 |
| Library | 114 | 185 | 109 | 16 |

schools in 1983–1984 to 27 per computer 5 years later to just under 6 students for each computer in 1999. The numbers represent the staggering financial investment made by schools across the country in just over 15 years ("Technology Counts," 1997, 1998, 1999).[6]

The Internet explosion triggered an unremitting drive to make computers available to all students. Wiring schools and classrooms is another measure of student access to new technologies. In 1994, 35% of schools were connected to the Internet. In 1999, wiring of at least one site in a building increased to 90%. In 1994, 3% of all classrooms were connected to the Internet; 3 years later, 27% were wired ("Technology Counts," 1999).

Another means of measuring access to computers is to determine the placement of computers in labs, in classrooms, and in media centers because machines and wiring are distributed among these settings in most high schools. Tables 2 and 3 display access to computers and Internet connections nationally, in the state of California, and in the two high schools ("Technology Counts," 1997). Missing from Tables 2 and 3 are the technology courses offered and the days set aside for instructing teachers and administrators how to use the hardware and software. Also absent are data on the on-site technical support provided by designated teachers and their cadre of highly skilled student assistants. By popular measures of availability, both high schools are characterized as technology rich.

Furthermore, teachers and students had access to computers at home. In our study, we asked teachers and students whether they had computers

Table 3
**Internet Connectivity, 1997–1998**

| Access | Nation | California | Flatland | Las Montañas |
|---|---|---|---|---|
| Classroom (%) | 44 | 44 | 64 | 80 |
| Lab (%) | 54 | 55 | 80 | 100 |
| Library (%) | 70 | 50 | 100 | 100 |
| Schools where teachers have E-mail(%)[a] | 39 | 35 | 100 | 100 |

[a]Percentage is calculated for schools that have at least 50% of their teachers with e-mail addresses.

at home, how often they used them, and what uses they made of them. Surprisingly, we found that home use by students and teachers is frequent and spans many applications, exceeding both students' and teachers' uses during classroom instruction.

### Teacher Use

Tables 4–6 suggest no "digital divide" between the two high schools, which have a high percentage of minority students and a moderate number of low-income students. Access at home and school exceeds California and national figures.[7]

Given the amount of access afforded teachers and students at these schools, how are the available computers used for instruction? In both high schools, teacher use of computers was similar. Each classroom had one computer for the teacher's use. There were 5 labs at Flatland and 10 labs at Las Montañas, some of which were restricted to certain students (e.g., those taking English and computer-assisted design classes or those taking the advanced multimedia course). In the media center/libraries at each school, computers are open to all teachers on a sign-up basis. In both schools, teachers reported that they largely used school computers to prepare for classes (Table 7).

Many teachers in both schools chose to take their students to the media centers where there were sufficient machines to accommodate an entire classroom for one or more periods. The figures in Table 8 show that one half to three fourths of the teachers used the media center, suggesting serious and occasional use among teachers in both schools. These numbers, however, are misleading. A few teachers (25% in one school and 32% in the other) in three departments (English, science, and social studies) accounted for 60–70% of all machine use in the media centers. In other words, almost two thirds to three fourths of the teachers who taught academic subjects in both schools were nonusers of the media centers' resources. Data from students' and teachers' interviews and surveys of both staffs reinforced the basic point

*Table 4*
**Percentage of Students and Teachers With Computers at Home**

| Flatland | Las Montañas | National |
|---|---|---|
| Students: | | |
| 85 | 90 | 56 (1997)[a] |
| Teachers: | | |
| 76 | 85 | 80 (1998)[b] |

*Note.* Figures for students and teachers taken from surveys administered in April and May 1999.
[a]Data from the U.S. Department of Commerce, Bureau of the Census (1997, Table 425, p. 482). Unpublished data, Table 425, p. 482.
[b]Data from Becker, Ravitz, and Wong (1999b).





*Table 5*
**Frequency of Home Use in Two High Schools, 1999**

| | Flatland | | Las Montañas | |
|---|---|---|---|---|
| Frequency | Teachers | Students | Teachers | Students |
| Serious use[a] | 82% | 86% | 84% | 67% |
| Occasional use[b] | 13% | 7% | 13% | 10% |
| Nonuse | 5% | 7% | 2% | NA |

*Note.* Figures for teachers were taken from surveys administered at faculty meetings in April and May 1999; figures for students were taken from surveys administered in schools in April and May 1999.
[a]At least once a week.
[b]At least once a month

that there was a general lack of technology usage among teachers in classrooms, labs, and media centers.

### Student Use

We shadowed 12 students 1 day each, at Flatland and Las Montañas, covering each grade level and all academic subjects. In these classes, we observed 35 teachers (one fourth of both faculties). On randomly chosen days, we observed that 9 of these 35 teachers (in computer courses, social studies, and Humanities—integrated English and social studies—classes) had students working at computers typing, doing Internet searches, and projects. The other 26 teachers in social studies, science, English, math, and foreign language used a familiar teaching repertoire: lecture, review of homework, recitation, and whole-group discussion. Four of the 26 used slides, videos, or overhead projectors for part of the periods we observed.

*Table 6*
**Types of Use at Home Reported by Teachers, 1999**

| Type | Flatland (%) | Las Montañas (%) |
|---|---|---|
| Personal use | 76 | 85 |
| Prepare school materials | 72 | 73 |
| Use E-mail | 71 | NA |
| Internet searches | 64 | NA |
| Prepare tests | 63 | 65 |
| Prepare lesson plans | 57 | 58 |

*Note.* All figures for Flatland teachers were taken from a survey administered at an inservice meeting in April 1999. The response rate was 77%. Las Montañas results were taken from a survey in October 1998. The response rate was 83%.

*Table 7*
**Types of Use at School Reported by Teachers, 1999**

| Type | Flatland | Las Montañas | National[a] |
|---|---|---|---|
| Word processing | 71 | 76 | NA |
| Keeping grades on students | 56 | 59 | 58 |
| E-mail | 51 | 85 | NA |
| Internet searches | 47 | 68 | 24 |

[a]National figures are for 1998. Becker, Ravitz, Wong (1999a), p. 32 [I averaged percentages for four academic subjects that were reported in the study.]

We interviewed 33 student volunteers including the 12 we shadowed. They reported serious to occasional use of computers and other technologies (including videos, television, laser disc players, and overhead projectors) in English and social studies classes and in tech-heavy classes such as business, drafting, multimedia, and computer networking at different grade levels. They used computers for word processing, doing Internet searches, and completing projects. For the majority of their academic classes, however,

*Table 8*
**Teacher Use of High School Media Centers**

| | Flatland | | Las Montañas |
|---|---|---|---|
| Use | 1997–1998 | 1998–1999 | 1998–1999 |
| Percentage of faculty who brought classes to center | 55 | 48 | 74 |
| Median number of days teachers who brought classes to the center used computers | 4 | 5 | 12 |
| Median percentage of yearly instructional time[a] | 3 | 3 | 8 |
| Median number of periods teachers used computers in center | 9 | 8.5 | 34 |
| Median percentage of yearly instructional time[b] | 1 | 1 | 5 |

[a]The median percentage of yearly instructional time refers to the number of days in above row.
[b]Median percentage of yearly instructional time refers to the number of periods in above row.





students reported little to no use of computers but did mention teacher use of videos, television programs, and overhead projectors.

Finally, we administered a survey to one fourth of each school's enrollment on 1 day and at the same time to avoid duplicating student responses. We polled students representing all academic subjects covering all grades in the high school. Students reported some computer use in English and social studies and little to no use in math, science, and foreign language. They reported low-level use such as typing assignments, working on reports, and doing Internet searches. High-level use included multimedia presentations, database analysis, and collection and interpretation of original data for a project. These results converge with national data.

There was as much variation within a department as there was between departments. For example, in the English department, one or two teachers were especially heavy users of computers, a few were occasional to rare users, and the rest were nonusers. This pattern was similar across departments.

There were students whose lives changed with increased access to technology. We called them "open door" students—their computer competence enhanced their self-confidence and motivation to do well in school, hence opened doors to learning. We also identified "tech gods." These were students who were recognized by adults in the school and fellow students for their substantial expertise and who spent time in technology-based electives.[8]

Several patterns emerged regarding open door students. They were predominantly, although not exclusively, male and from varied ethnic backgrounds. Whether aided by family, friends, or were self-taught, all had gained their expertise outside of school, usually on home computers. As one student explained, "I started with my Dad's Atari, then moved to his 486 in sixth grade . . . learning on your own is better." Another added that he had gained little experience at school, but "a lot at home." They reported heavy home use whether engaging in complex tasks such as repair and programming or simply completing their homework. All were aware that their expertise far surpassed that of most of their classmates.

Open door students were candid about having access to computers in schools. "It's an outlet," one student said, "where I am good at something, where I can produce good work and get good feedback." Another student simply said: "I am good at computers so I am good at school." Many of the open door students used their technological expertise to help teachers and fellow students.

Student computer experts were vital to the two high schools. At Flatland, expert students in a social studies class created a web club that helped their teacher keep the school's site filled with compelling, up-to-date content. Another student helped a science teacher to create a program to monitor the sites that his students surfed.

Student computer experts eased the demand placed on an understaffed and overburdened technology support team. At Flatland, the official support

staff consisted of one teacher who also taught three classes; at Las Montañas, it consisted of one full-time tech coordinator. These teachers were responsible for establishing the school's network, maintaining 300 or more computers, writing grants for new equipment, and determining the school's technology policies. Tech coordinators cultivated select cadres of technologically proficient students to help them meet these challenges.[9] There were only about 5 such students in each school, representing 5% of the total student population.[10]

## Did Teachers in the Two High Schools Who Used Computers in Their Classrooms for Instruction Maintain or Alter Their Core Teaching Practices?

In interviews with the 21 teachers, 13 (just over 60%) said that their teaching had changed because of their use of information technologies. They planned more efficiently, communicated with colleagues more often via e-mail, and secured information from the Internet. They noted the importance of having an additional tool to use in their customary repertoire of teaching practices. They saw students' direct access to information as a phenomenal enhancement to their teaching.

A young social studies teacher explained:

> [T]he technology has just given me more tools to use. . . . One thing I think it has allowed me to do is to access certain students who need something kinetic. . . . Like the students who made the video aren't the kind of students who are going to write and debate the question: does democracy really exist? Because there are other students who can debate with so much more power that they are intimidated. . . . Here is a way for them to convey their message about the question and to feature it at the beginning of the [video]. Something they are proud of that the rest of the class clapped after they saw it. It really brings them into the class and allows their ideas to be viewed and valued.

A special education teacher explained how computers had changed her teaching:

> From the first year of using the computer maybe to retype rough drafts or essays to . . . working on the Internet to actually having students in there for 1,2,3 days . . . and just letting them go to town.

Only 4 of the 13 teachers said that they had modified their classroom in major ways. They organized their classes differently, lectured less, relied more on securing information from sources other than the textbook, gave students more independence, and acted more like a coach than the performer on stage. They became more student centered in their teaching; they had made fundamental changes in their pedagogy.





When we shadowed teachers and students, all but a few of the teachers in both schools used a familiar repertoire of instructional approaches. These included lecturing, conducting a discussion, reviewing homework, working on assignments, and occasionally using overhead projectors and videos. Even in computer-based classes, teacher-centered instruction was the norm.

Our observations of teachers in the two schools are consistent with reports in the literature (Cohen, 1988; Goodlad, 1984; Rosenholtz, 1989; Sarason, 1971). Many have argued that new technologies would eventually transform teacher-centered practices into student-centered ones (Cetron & Gayle, 1996; International Society for Technology in Education, 1999; Papert, 1993). Except for the four teachers identified above, we saw little evidence of more student-centered instruction.

These four teachers said that using technologies in their classroom had not only helped them prepare for classes but also had helped make their classrooms more student centered. We do not know whether classroom changes occurred due to the technologies they used or whether they had emerged as part of a gradual shift in their beliefs about teaching in which the computers supplied a vehicle for making changes they had already decided to make.

Incremental changes in teaching style occurred as a consequence of enhanced accessibility to new technologies (especially computers). However, few fundamental changes in the dominant mode of teacher-centered instruction have occurred. Occasional to serious use of computers had marginal to no impact on established teaching practices. A classroom revolution has not occurred.[11] Most teachers in the two high schools adapt technology to fit the familiar practices of teacher-centered instruction.[12]

## Explaining the Anomalies

How do we explain the unexpected outcomes in two California high schools that challenge the assumptions of policy makers determined to make high schools into high-tech, productive places? With outstanding access to computers, why do most teachers use the technology in classrooms infrequently and in limited ways? Why do the teachers who do use computers for instruction typically use the technology to sustain common teaching practices?[13]

We studied only two high schools in one state. Therefore, we can only speculate about the reasons for the discrepancies between high access and low-end use of information technologies in classrooms. As a major investment of funds, teacher and administrative time, and school resources have been made, an explanation of meager results in frequency of teacher and student technology use and instructional change is worthwhile for those interested in the relationships between policy and actual classroom practices.

The data gathered from both schools confirm at least two of the reasons commonly offered for limited and infrequent computer use in classrooms

and maintenance of teacher-centered instructional practices. First, teachers do not have the time to find and evaluate software. Second, computer and software training was seldom offered at convenient times. Although there were many district opportunities and on-site sessions to learn general computer skills, the generic training available was irrelevant to teachers' specific needs.

Teachers' age, experience, and gender were not factors. There was little difference in computer use between veteran and novice teachers, between those with or without previous technological experience, or between male and female teachers. We did not find teacher resistance or technophobia, reasons often cited in studies of teachers' use of computers. Based on faculty interviews and survey data at both schools, teachers who called for more and better technology were avid home computer users. They believed in the future ubiquity of computers in society.[14]

The uneven usage of new technologies in the two high schools and the stability of teacher-centered forms of instruction can be explained historically in at least two ways. We use the word *explanation* as shorthand for a conceptual framework, a way of seeing the anomalies and accounting for them. Embedded in these explanations are the seeds of policy recommendations.

First, there is the "slow revolution" explanation, an idea that small changes accumulating over time create a slow-motion transformation. This explanation is anchored in the notion of lag time between the invention of a new technology, the adoption of innovations, and the slow spread of its virtues through the general population. Individuals and companies need decades to learn how to use and manage the new technology.

According to Economist Paul David (1990), all of the technical developments to make the commercial applications of electricity existed by the 1880s. However, it was not until the 1920s that companies harnessed electric power to manufacturing, production, and distribution of products. It took almost 50 years for the steam engine as applied to the textile industries to give rise to the factory system, a working class, and the effects of urban growth to be felt on the family, public health, and schooling. Like the steam engine, the computer is both symbol and trigger of major institutional and economic changes (Drucker, 1999).

Under the slow revolution explanation, teachers' adoption of personal computers for instruction began with many teachers using computers for classroom preparation and communication. Increasing numbers of teachers will embrace integration of technology in the classroom over time (Rogers, 1995). This explanation offers a gradualist, incrementalist view of change, one that is clearly anchored in the belief of inevitable technological change. It implies that the infrequent and limited classroom use of technologies will dissolve. Previous research on teacher use of technological innovations for instruction and our experiences as high school teachers leave us dubious about the effect of the slow revolution (Cuban, 1986).[15]





In the second explanation we emphasize the context of high schools, their structures, use of time, and the flawed nature of the technological innovation itself. Moreover, this explanation tries to account for the sustaining of teacher-centered practices. Serious and occasional users of technology have continued routine instructional practices because of contextual factors rather than individual factors of hostility to technology, inertia, or passive resistance.

### Historical Legacy

The comprehensive high school is about 75 years old although its antecedents can be traced to the early decades of the 19th century. Its goal was to prepare students for college. Modeled initially after the small liberal arts college, high schools were organized by departments and attracted teachers who were trained in separate academic disciplines. Their primary task was to transfer knowledge, skills, and moral values to the next generation within a daily schedule of 45–50 minute periods. As the goals of high school expanded to prepare students for industrial and commercial job markets, to build citizenship, and to mold character, vocational departments, extracurricular activities, and student government were added. By the 1920s, the comprehensive high school emerged, as we know it today (Hampel, 1986; Krug, 1964; Reese, 1995).

As decades passed, some comprehensive high schools focused on college preparatory curricula while maintaining a modest array of vocational courses. Other high schools offered more vocational-oriented curricula. These embedded patterns of departments, 50-minute periods, and diverse curricula form the historical residue and the commonplaces of high schools that frame the familiar teaching practices that characterize secondary classrooms. Initiating change is difficult because established practices are taken for granted and are seldom questioned by policy makers, practitioners, researchers, and taxpayers.

### Structures and Time

The earliest high schools had departments, teachers drawn from separate academic disciplines, and time schedules that divided the school day into periods to accommodate all curricula. These institutions expanded to accommodate thousands of students, hundreds of staff, and bureaucratic rules to keep the organization operating smoothly. At Las Montañas, there are about 1,300 students and a faculty of about 60 teachers. It has a daily schedule of six periods, each one 55 minutes long.

The structure of the six-period day made it difficult for teachers trained in separate disciplines to adopt innovations and engage in school reforms that required them to cross subject boundaries and team with other teachers. Few teachers shared common periods to plan; there was little time to observe colleagues' classrooms; and there was even less time to prepare for five classes a day. The cellular organization, time schedule, and departmental boundaries considerably reduced cross-fertilization of ideas within and

across departments. Innovations that encouraged diversified teaching approaches, including the use of computers to enhance instruction, occurred in a few classes where teachers shared ideas, planned, and watched one another teach.

On two occasions, the Las Montañas faculty deliberated changing the daily schedule. A majority of the teachers rejected a proposal to end the six-period day. A year after the second rejection, interviews with many teachers suggested that much skepticism remained about longer time blocks leading to major changes in student learning. Deep divisions among teachers over the potential pedagogical impact of changing the traditional schedule stalled a collective effort at schoolwide reform. As a result, the departmental and time schedule structures have kept informational technologies confined to dedicated individuals in departments who are largely divorced from schoolwide curricular and instructional decisions. Teachers also said that they did not have enough time in the school day, much less at home, to do all of the things they were expected to do and then find time to integrate computers and other technologies into their classroom routines.

Teachers told us that they did not have enough time to incorporate computers into their daily teaching. They would need hours to preview web sites; hours to locate the photos they required for the multimedia project they assigned to students; hours to scan those photos into the computers; and hours to take district or corporate courses to upgrade their skills.

The issue of insufficient time was repeated often by faculty, particularly the serious users. Teachers like Alison Piro made it clear that using computers in their classes made demands upon them that made their job harder. As pioneers, they were willing to work longer hours, but they paid a personal price in exhaustion and an eventual exit from the school for this type of dedication. Occasional, rare, and nonusers were already rushed in their daily schedules. Where, they asked, would the additional time come from? The issue of inadequate time in the daily schedule to plan work together goes to the heart of teacher use of new technologies and their preferred teaching practices.[16]

There are other considerations that affect classroom uses of technology. Consider how external tests, departmental organization, secondary teachers' disciplinary training, and self-contained classrooms encourage teachers to behave as academic specialists whose primary concern is covering the body of information contained within a text in 36 weeks. Most high schools have chosen to deploy their computers into labs and media centers rather than to individual classrooms. This decision reflects, in part, the preferences of academic specialists lodged in departments who decide how best to use their limited time.

A few dedicated teachers have become serious users and have made fundamental changes in how they teach. We cannot generalize that all or even most teachers will follow their lead. What we have seen in the two high schools and in the literature on teacher turnover is that an increasing number of computer-using teachers eventually leave teaching or move on to other





technical or teaching positions that provide them with more time, higher salaries, and more advanced and reliable technology. Teacher turnover undermines the implementing and institutionalizing of technological innovations and contributes to maintaining common teaching practices.[17]

### Defects in the Technologies

The historical legacy of comprehensive high schools and their organization, including the time schedule, helps to explain the infrequent teacher use of computers in classrooms and the stability of teaching practices in the face of high home use of technology and its ample availability on campus. Teachers also said that the technology itself is unreliable and they expressed deep ambivalence about powerful machines that often broke down.

We heard repeatedly from administrators, coordinators, teachers, and students about inadequate wiring, servers crashing, and constant replacement of obsolete software and machines. Hardcore advocates of technology prepared back-up lessons just in case the Internet search, the on-line curriculum, Power-Point presentation, or word processing program would disappear either because a server went down or because the system was too slow to warrant using it at all.

Even at schools with technology coordinators and rapid-response student assistants on-site, technical problems could not be fixed immediately. The support teams provided triage technical assistance and taught many teachers to trouble-shoot their problems before calling. However, support personnel were often overwhelmed by teacher requests, out of replacement parts, or they just could not respond swiftly or adequately.

Professionals who depend on technologies on a daily basis require reliable machines and software. If technical glitches occur weekly or a few times a month, then confidence in the technology's worth erodes and contributes to sustaining current teaching practices.

We offer these explanations (and they are, of course, not mutually exclusive) to reconcile the discrepancies between our observations and policy makers' beliefs in high access that would lead to major improvements in teaching and learning. Speculative as they are, both explanations are based on interviews with teachers and students, our knowledge of high schools, and the uses of information technologies nationwide and in the past century.

The slow revolution explanation may appeal to those who see the inevitable victory of technological progress. Within this view, more and more teachers will become serious users of computers in their classrooms as the infrastructure matures and teachers' beliefs about teaching and learning evolve. For those who find such an explanation convincing, certain policy tasks emerge as recommendations: Speed up the process of making computers readily available to each student in each classroom; increase on-demand technical support for teachers.

The second explanation, which focuses on history and contexts, suggests more complex, deeply embedded factors that will retard widespread

use of technology in classrooms and substantial changes in teaching practices. Fundamental changes would need to be made in how schools are organized, how time is allocated, and how teachers are prepared. Hardware manufacturers, software firms, and telecommunication companies would need to improve product reliability to limit the defects in their wares, expand technical support to teachers, increase speed of Internet connection at little cost to schools, and test software on consumers prior to marketing them to district and state administrators. Without such major changes, only modest, peripheral modifications will occur in schooling, teaching, and learning. Teachers will adapt innovations to the contours of the self-contained classroom. New technologies will, paradoxically, sustain old practices.

We are not prophets. We cannot say which of these explanations or the interaction between the two explanations will account for what occurs in schools at the end of the next century. We do know that the prevailing assumptions guiding policy on new technologies in schools are deeply flawed and in need of reassessment.

Our hunch is that the accumulation of ad hoc incremental changes as suggested by the slow revolution will alter some aspects of high school teaching and even part of the context that we described. We might envision a day, for example, when all students use portable computers the way they use notebooks today. The teacher, in turn, might post math homework assignments from the text and appropriate links on her web site which students access from home.

We also believe that this ad hoc incrementalism will only marginally reshape the deeply entrenched structures of the self-contained classroom, departments, time schedules, and teachers' disciplinary training that help account for the dominant teacher-centered practices. The teacher in the above example would, in this sense, use the laptops to sustain existing practices (e.g., homework assignments). In short, historical legacies of high schools in their school structures and technological flaws will trump the slow revolution in teaching practices. In 2050, the typical American high school classroom should be familiar terrain to great-grandparents of the time who could slip behind a schoolroom desk and recognize teaching and learning from their own youth.

## Notes

[1]All school, teacher, student, and administrator names used in this article are pseudonyms to protect the privacy of those who volunteered their time, ideas, and classrooms to our research team.

[2]All direct quotes were taken from interviews with teachers and from direct observations in classrooms.

[3]Claris Works is Apple software that includes art, drawing, database, and spreadsheet applications; AVID is a video-editing software program.

[4]The accurate determination of use of computers by teachers in the classroom is difficult. Machines and software are distributed in most schools among labs, libraries, and classrooms. Statistics and figures that estimate the ratio of students to computers are misleading. A low ratio of students to computers infers high access, but inferring high use





by teachers and students may not be accurate. Most statistics are derived from surveys of school officials and self-reports from teachers. Although this information is helpful, overestimates of use are common. Combining classroom studies with teacher reports and student reports of computer use offers increased reliability (Becker, 1986; Cuban, 1986).

[5]For examples of these assumptions about access and use in schools leading to jobs see CEO Forum (1999) and Council of Chief State School Officers (1992).

[6]The cost of both hardware and software vary. The cost of current hardware in schools (as of 1996) is about $3 billion. To deploy computers into one 25-PC networked lab in each school would cost $11 billion; for a networked PC for every five students, the estimated cost would be $47 billion (Coley, Cradler, & Engel, 1997). Software purchases for 1998 totaled $571 million, up from $473 million in 1996 ("Technology Counts," 1999).

[7]We say "suggest" because we collected no data on socioeconomic status from our interviewees or on the student surveys. 1998 U.S. Department of Commerce Census Bureau data point out sharp differences between Internet access for minority families earning $75,000 or higher and low-income families. The differences, however, dissolve when Blacks and Whites earning $75,000 or higher are compared. There is no "digital divide" in home ownership of computers at the two high schools. There is, however, an in-school "divide" in classroom use that we examine in great detail. (http://www.ntia.doc.gov/ntiahome/fttn99/execsummary.html)

[8]This section on open door and tech gods students is taken from an unpublished paper by Peck, Cuban, and Kirkpatrick (2000). We identified only one female student among these students. For an examination of gender differences on highly expert students in a computer science department at a university, see Margolis, Fisher, and Miller (2000).

[9]Nationally, 30% of schools have a full-time tech coordinator, 27% have a teacher or other staff performing some of these duties, 20% have district staff, and 10% have a part-time coordinator for tech support. Other tech staff comprised volunteers and contracted tech support. Two percent of the schools have no coordinator or volunteer ("Technology Counts," 1999).

[10]Our estimate combines the handful of students that teachers identified as tech gods and open door students with the enrollment totals in tech-based electives and academic courses with serious technology-using teachers.

[11]The distinction drawn between incremental and fundamental changes in teaching practice and school reform are described and analyzed in Cuban (1993, 1999).

[12]One reviewer raised an important issue: Most classrooms had only one computer. Teachers had to take their students to the media center or an available lab (except for those teachers in the business and computer departments who had rooms with 25 to 30 machines). In the words of the reviewer, the classroom "is hardly a technology rich environment." Thus, the school may have been abundantly outfitted with new technologies for instruction but the classroom had meager access. There were two classes at Flatland (biology and history) and Las Montañas (English and social studies) that had six to eight computers in each room available to students and teachers daily. Also at Las Montañas, there was a mobile cart with four to six computers that teachers could bring to their rooms. We observed these classes and discovered that teachers directed students to use the computers a few times a week for particular activities, such as word processing and Internet searches. The familiar teacher-centered patterns we observed in classrooms and the limited use of the machines suggest—and that is the strongest word we can use given the limited number of classrooms we saw—that multiple computers in a classroom had not led to many alterations in teaching practices. At the school level where labs and the media center provided access to computers for instruction, we found that the media centers and labs were not booked the entire school day. Our estimate is that the labs went unused at least one third of the time. Our data suggest that the overall patterns we noted would not have changed were there more computers in each class. Other studies of high school teachers and students use would need to be done where classroom access to computers is in the 4–6 range per classroom to determine whether the patterns we noted in these two high schools were unique.

[13]To make plain our main premise, we do not assume that adopting new technologies for instruction in of itself is an unalloyed good. To the degree that teachers' and students' uses of computers make learning better and more efficient, we endorse such uses. To the

degree that teachers' and students' uses of computers reveal only comparable quality and efficiency to non-computer using classrooms, the social and economic costs of such an investment need to be carefully considered before additional financial commitments are made.

[14]Lists of obstacles, constraints, and problems that block teacher use of computers are documented in books and articles and in exhortations by advocates of placing more machines in classrooms (President's Committee, 1997; U.S. Congress, Office of Tech Assessment, 1995). Age, gender, and teacher resistance as explanatory factors are seldom made explicit in current policy debates. In our discussions with teachers, students, and administrators, we found explanations such as older teachers are too rigid, females are nontechnical, and teachers fear job loss or retirement and become closet Luddites. We found no conspicuous evidence of teacher resistance; in fact, we found enthusiasm for home and school use for class preparation, communication, and administrative tasks. We also noted that female and male teachers owned computers in roughly equal proportions and that many older teachers in the school were both serious and occasional users.

[15]Schofield (1995) did one study of computer use in high schools in the mid-1980s. She found that contextual factors had a profound influence on which teachers used computers for instruction, how the machines were used by students in classrooms, and the limits of technology use in the school itself.

[16]For a teacher's and parent's point of view about the centrality of time in school change, see Swaim and Swaim (1999).

[17]This is exactly what has occurred at Las Montañas. Since 1997, the "intellectual capital" of technological expertise and conceptual reform within the school has begun to slip away. Of the five serious users who taught academic subjects in the school during 1998–1999, three, including Alison Piro, resigned for positions elsewhere. She began a charter school and the other two teachers left for higher salaried posts in districts where housing prices were less than in Silicon Valley. Flatland experienced similar losses with the departure of a technology teacher who had been one of the first to use computers extensively with his classes and a social studies teacher, another serious user who had recruited his students to maintain the school's website. Although these teachers took their expertise to other schools, Flatland and Las Montañas endured losses of a scarce resource.

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